Volume 14 Number 3

COMMONWEALTH OF AUSTRALIA

JOURNAL

OF

THE COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

AUGUST, 1941

Registered at the General Post Office, Melbourne,
for transmission by post as a periodical

C.7619/41.

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314 Albert Street,
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Registered at the General Post Office, Melbourne, for transmission by post as a periodical

C.7619/41.

H. E. Daw, Government Printer, Melbourne

(PUBLISHED QUARTERLY)

Journal of the Council for Scientific and Industrial Research.

Vol. 14. AUGUST, 1941. No. 3.

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(PUBLISHED QUARTERLY)

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A Nomogram for the Determination of the Cost of Maintenance Rations for Sheep.

*By E. W. L. Lines, B.Sc.**

For several years, one of the major research projects of this laboratory has been the determination of the relative capacity of various fodders to provide the energy necessary for the maintenance of sheep. Assessment of the comparative values of the variety of roughages, concentrates, &c., which are suitable for this purpose involves highly technical procedures. The methods utilized will be discussed in detail in other publications in which the extensive experimental data obtained by a team of workers in this laboratory will be presented. A portion of this information is used here as a basis for the construction of a nomogram from which may be determined the comparative feeding values of a number of fodders that are feasible for hand-feeding sheep during drought, and, providing the cost of the individual fodders delivered to the site of feeding is known, it may be used to determine the cost of the maintenance of sheep. Notwithstanding the fluctuation of market prices, the most economical ration to employ may thus be readily determined from the nomogram.

Expression of data by means of a nomogram will no doubt appear strange and novel to most of the individuals for whom this has been prepared. Presentation of data in this form, however, is commonplace in scientific literature, as it obviates the necessity of bulky tables of figures. With a little practice the desired information may be obtained quickly and simply from a nomogram.

In general terms, a nomogram consists of three or more scales arranged so that a straight line drawn through selected values on any two of them will cross the others at values determined by the two selected values. The one presented here consists of two sets of three scales, one of which is duplicated in either set. The first set may be used to reduce the price per ton and the feeding value of the fodder under consideration

* An officer of the Division of Animal Health and Nutrition, located at the Nutrition Laboratory, Adelaide.

to a common unit "the equivalent price of wheat".* From this equivalent price of wheat the second set may be used to determine the cost of a full ration for sheep of various live weights.

The scale representing the comparative feeding values of fodder and the scale for the live weight of sheep are divided with two sets of graduations, one, on the right, for cold and wet weather, and the other, on the left, for warm weather. The reason for this is that under cold, wet conditions, not only is it necessary to provide more fodder so as to maintain body temperature, but also the comparative feeding values of fodders are altered under these conditions. Roughages such as hay or grass straw provide a considerable amount of energy which is useful only for the maintenance of body temperature. This energy is wastefully dissipated when there is no call for extra energy to provide additional heat. In consequence, these fodders increase in feeding value when the environment is cold.

As the nutritional value of different samples of the same fodder may vary as much as 10 per cent., no advantage may be gained by attempting to read the scales more closely than to the nearest individual graduation. These are drawn at approximately 5 per cent. intervals.

A ration composed of a mixture of two or more fodders is often more valuable than one composed of any individual fodder. This especially is so when the poorer roughages, such as cereal hay or straw, constitute the major part of the rations, in which case it is desirable to add a proportion of a concentrate such as oil cake or lucerne hay. To calculate the amount of mixed ration, divide the number of sheep to be fed in the proportion it is desired to mix the fodders. Use the nomogram to determine the amount of each fodder alone that is necessary for the corresponding section of the flock, and mix the fodders in the amounts so determined.

Pregnant ewes should be supplied with a ration which would maintain a non-pregnant ewe which is 20 lb. heavier in live weight. Rams require from 10 to 20 per cent. more fodder than ewes of equal weight.

Directions for Use of Nomogram.

1. Find the cost in *shillings* per long ton (2,240 lb.) *at the site of feeding,* of the most likely fodders.

2. From this cost of the fodder on the A scale, stretch a thread or place a rule to the point on the B scale for that fodder and note where it crosses the C1 scale to show the "equivalent price of wheat". Note that the C scales read from top to bottom, the reverse of the others. The fodder which shows the lowest equivalent price of wheat will afford the cheapest ration. If the price plus freight exceeds 200s. per ton, use half the cost and double the final answer read on either the C or E scales.

* "The equivalent price of wheat," i.e., the cost in pence that wheat would be a bushel if it were to provide a ration of the same cost as the fodder under consideration, is used as a common reference unit. Obviously the individual fodder which has the lowest value for the equivalent price of wheat will provide the most economical ration. The feeding value of wheat does not alter appreciably with weather conditions.

3. From the equivalent price of wheat on scale C2, a straight line over the average live weight on scale D crosses scale E at the cost per 100 sheep per day in pence.

Warm or Cold Weather Scales.

In ordinary weather use the graduations on the *left* side of scales B and D marked "Warm". If the weather is cold and wet or cold and windy, use the graduations on the *right* side of scales B and D marked "Cold".

4. To find the weight of the ration, start from the point marked R (1d. per lb.) on scale A and the cost so found on scale E will give the weight of the ration in pounds per 100 sheep per day.*

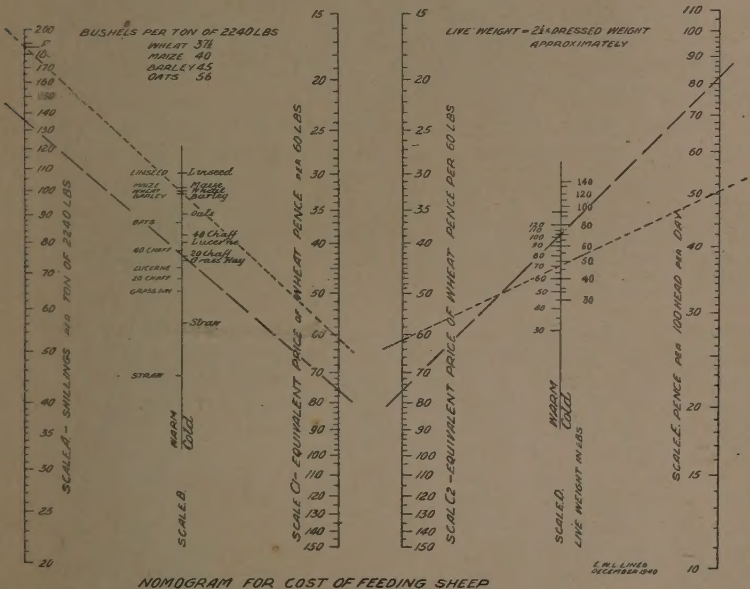

Fig. 1.

Example of Use of Nomogram.

What is the cost of a maintenance ration for 100 sheep per day when feeding on: Oats at 2s. 6d., barley at 3s. 2d. per bushel, or on wheaten chaff at 90s. per ton? Freight is 45s. per ton; live weight of sheep is 70 lb.

Warm Weather (left side of scales B and D).

Cost Delivered. Per Ton. Scale A.		*Equivalent Wheat. Pence/bushel. Scale C.*	*Cost per 100 Sheep. Pence. Scale E.*	*Lbs. per 100 Sheep/day.*
Oats	185s.	78d.	64d.	65
Barley	187s.	61d.	51d.	51
Chaff	135s.	92d.	76d.	105

* Or alternatively multiply the cost by 187 and divide by the cost in shillings per ton of the fodder under consideration.

Cold Weather (right side of scales B and D).

Oats	72·5d.	78d.	79
Barley	61d.	67d.	68
Chaff	76d.	82d.	114

An illustration of the nomogram to a reduced scale is shown in Fig. 1. Two of the examples given above, viz., barley for warm weather and chaff for cold weather, are shown in it by means of dotted and broken lines respectively. The original nomogram is issued separately on board sized 12 in. x 10 in.

Notes on Fodders.

Cereal Hay.—The feeding value of cereal hay or chaff depends on the percentage of grain that it contains. Two points are shown, that for highest grade containing 40 per cent. grain, and that for average long-stem wheaten containing 20 per cent. grain. Lower grades and green cut hay are equivalent to grass hay.

Lucerne Hay.—Although little more efficient than cereal hay when it is the only feed, lucerne hay is an excellent supplement to grass straw.

Oil Cakes.—Linseed cake, cotton seed cake, &c., are the high-grade protein concentrates suitable for supplementing low-grade roughages. Oil cakes as well as mill offal are quoted in tons of 2,000 lb., and the price should be adjusted to tons of 2,240 lb. by multiplying by 1.12 before using the nomogram.

The Importance of *Rhizopertha dominica* as a Pest of Wheat under Wartime Storage Conditions.

By F. J. Gay, B.Sc., D.I.C., and F. N. Ratcliffe, B.A.**

1. General.

Grain-eating insects constitute the chief threat to the safety of wheat that has to be stored for lengthy periods. In most attempts to assess, and to recommend measures for combating this threat to stored wheat in Australia, attention has been focussed almost exclusively on the grain weevils, *Calandra oryzae* L. and *C. granaria* L., while the lesser grain borer, *Rhizopertha dominica* Fab., has received relatively little attention. (This tendency is well illustrated by the summary of available information on wheat weevils and their control which appeared in a recent issue of this *Journal* (1), and by a series of articles by Davidson (2) in the *Journal of Agriculture of South Australia.*) Nevertheless, during the years 1917-19, *Rhizopertha* gave a large-scale demonstration of its destructive powers in this country. Recent observations, combined with the results of some preliminary laboratory studies, indicate that in Australia *Rhizopertha* is likely to prove of greater importance as a pest—possibly of much greater importance—than the true grain weevils.

Whereas 25 years ago all the wheat in Australia was handled in bags, to-day a considerable part of the crop is handled and stored in bulk. Although Australian wheat goes into storage at a moisture content which, in other parts of the world, would be regarded as amply low enough to ensure its safety from spontaneous heating, bulk wheat is liable to heat in this country; and the New South Wales silo authorities regard facilities for turning† almost as a *sine qua non* of safe wheat storage. Except for small uniform parcels, when wheat starts to heat it does so unevenly, and a mass of heating bulk grain will show temperatures ranging between, say, 75°F. and up to or even over 110°F.—figures which are of importance in connexion with the breeding of *Rhizopertha*. By no means all Australian wheat shows a tendency to heat in bulk; but wheat stored in silo bins will resist cooling much longer than will wheat held in bag stacks, and will retain something approximating to its initial temperature for considerable periods. Such data as are available indicate that wheat goes into store in this country at temperatures between 70° and 85°F.

It is unnecessary to give a description of *Rhizopertha dominica* here; but it might be mentioned that the insect is very easy to identify. Its lack of a "snout" distinguishes it at once from the two species of *Calandra*—the only other beetles which commonly bore into and hollow out wheat grains. Its cylindrical body with parallel sides, and its reflexed head (giving it the appearance, when viewed from above, of being truncated anteriorly) serve to distinguish it from the "secondary"

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* An officer of the Division of Economic Entomology.

† The process of turning grain in New South Wales silos is described, and its effect on the temperature of the wheat discussed, in an article by Gay (3) in a recent issue of this *Journal*.

grain pests, such as the flour beetles of the genera *Tribolium* and *Latheticus*, the saw-toothed grain beetle (*Oryzaephilus surinamensis*), and the small grain beetles of the genus *Laemophloeus*, all of which, in general, are much more active insects than the lesser grain borer.

Rhizopertha damage is characterized by the production of large quantities of floury-white frass, by which infestations can usually be identified even before examination reveals the presence of the insects themselves. The feeding adults have a habit of boring into wheat grains at several points (a drawing of a characteristic *Rhizopertha*-attacked grain is reproduced by Davidson in the publication cited above); and they do their work of hollowing-out very thoroughly, reducing wheat grains ultimately to dry empty husks. *Rhizopertha* occasionally indulges in mass flights, which can result in great irritation and annoyance to human beings, and have occasionally put a stop to all manual work in the vicinity while they lasted. These flights seem generally to take place in late afternoon during muggy weather such as occurs before rain.

R. dominica is an interesting insect in that it belongs to the family Bostrychidae, all other members of which are wood borers in both the adult and larval stages. It is thought that *R. dominica* was originally a wood-eating species, and that it has become adapted to feeding on grain in fairly recent times. Despite its importance to-day as a pest of stored grain, there are authentic records (see Potter, 4) of it attacking such things as stored drugs, leather, papers, army and ships' biscuits, wood of packing cases and casks, and the living wood and bark of various species of trees. It is possible that wood and bark may be readily attacked by this species in the field, for under laboratory conditions we have found that the adults will riddle bark corks with their galleries in a few days. This ability to bore into wood may have some significance in providing a means whereby the insect might carry over between seasons in stack dunnage.

In its world distribution, *R. dominica* must be regarded as tropico-cosmopolitan; but the special conditions associated with stored grain have enabled it to become established in many sub-tropical and warm-temperate regions. Potter (*loc. cit.*), in his review of the available records of this insect, states that it is a major pest of stored grain in India, the Argentine, and the United States of America, in addition to Australia.

II. History and Occurrence of *Rhizopertha* in Australia.

R. dominica was first officially recorded in this country during the "weevil plague" of 1917-19. In Western Australia it is generally believed to have been introduced into that State with a cargo of maize from South America; but it was probably established in Australia at a much earlier date. Froggatt (5) recorded it in 1918 as causing serious damage to wheat stacked near Sydney. Winterbottom (6) in his account of conditions in South Australia and Victoria during the last war period records the following observations on *Rhizopertha*, which he said "did an enormous amount of damage":—

> "Given favorable conditions, the rate of development of this insect is simply amazing. Very little was seen of this insect in the early days of the weevil plague. This stage was confined to

Calandra oryzae, but when *Rhizopertha dominica* commenced to attack wheat stacks that had already been attacked by *Calandra oryzae,* the development became very rapid indeed. The writer has often found that these insects, which fly very freely, have flown from a badly infested wheat stack, and then settled on a stack of sound, dry wheat, stacked in bags, have immediately attacked the grains showing in the seams of the bags, and although the characteristic floury frass is at once seen, the insects make very little headway or progress, and generally die out . . . It was found by the writer in all parts of South Australia, and in all the wheat yards in Victoria, and is mentioned by A. M. Lea as very prevalent in New South Wales. This is not to be wondered at, as all the wheat yards where it became a plague were situated close to a railway line. The insects, being very free fliers, would settle in railway trains passing along the main lines, and were thus transported for long distances. All railway trucks leaving the wheat yards were infested with them. At Wallaroo, where they became very bad indeed, they were found on the wing three miles away from the wheat yards. . . . In the campaign against weevil this insect gave considerable trouble owing to its boring activities. It bored through malthoid, leaving a characteristic clean-cut round hole . . . The attack on wheat by *Rhizopertha dominica*, the grain-boring beetle, seems to depend first upon attack by *Calandra*. In every yard where the *Calandra* became very bad there was later a plague of *Rhizopertha.*"

Winterbottom's observations on the dependence of *Rhizopertha* on previous attack by *Calandra,* and its failure to make headway in bags of sound uninfested wheat, are of particular interest. The proven ability of *R. dominica* to attack and increase in undamaged wheat (demonstrated daily in our breeding cultures) indicates that this species is not a specialized and destructive form of secondary pest, as Winterbottom's observations might at first suggest. From our knowledge of the temperature requirements of *R. dominica* (see below), we are inclined to believe that the observed failure of this insect to establish itself in stacks of clean wheat was probably due to the flights taking place at the beginning of a period during which the temperatures were not high enough to permit breeding. It seems probable also that the benefit derived by *Rhizopertha* from following in the footsteps, so to speak, of *Calandra* might have been due to the activities of the latter insects raising the temperature of the infested grain. Davidson (*loc. cit.*) quotes some unpublished observations of a colleague which showed that the average temperature of three bags of weevil-infested wheat in a South Australian shed was 20°F. higher than that of uninfested bags.

When the surplus wheat stored during 1917-19 was cleared, and normal handling conditions returned, *R. dominica* appears to have gone into eclipse in Australia. That is to say, until very recently, there seem to have been no outbreaks of the insect sufficiently serious to have attracted official attention. It is possible that the species may actually have died out—or at any rate been reduced to something near extinction —over considerable areas; but it is hard to believe that it has not managed to retain a foothold in all the mainland States. We know from our own observations that it has maintained itself successfully

in the New South Wales wheat belt; for we found *Rhizopertha* to be the chief primary pest species in bags rejected from the Homebush depot in June, 1940, and bags infested by this insect were also rejected from the Spring Hill depot. We saw it also in bags rejected from a parcel of wheat being shipped at Rozelle (Sydney); and it was the dominant species infesting wheat in the country silos in New South Wales at which fumigation tests were carried out in September and October, 1940 (see Fitzgerald, Ratcliffe and Gay, 7). One would expect Queensland to be the Australian stronghold of *R. dominica*, but there is little evidence that it is, or has been, prevalent there. When the writers visited that State in the winter of 1940, *Rhizopertha* was not noticed in any of the infested stacks examined, though some lumpers stated that they had often seen "the square-headed borer that makes such a mess of grain."

III. Results of Laboratory Studies of *R. dominica*.

During the early stages of the investigation by the Division of Economic Entomology into the problem of the control of wheat-infesting insects, attention was concentrated almost exclusively on the two species of *Calandra*. *Rhizopertha* was later used to an increasing extent in the various tests and experiments, and more recently work on this species has been intensified. The studies that have been carried out to date are incomplete and far from comprehensive, but they have yielded certain data which help to fill in the gaps in our knowledge of the biology of *R. dominica,* and to form an estimate of its probable importance during the next year or two.

R. dominica requires relatively high temperatures for breeding. Our attempts to develop stock cultures at 78·8°F. (26°C.) were unsuccessful. After two months at this temperature, the cultures were found to contain about the same number of living adult insects as were originally placed on the wheat. When the stocks were maintained at 90°F. (32·2°C.), however, the insects bred readily, passing through their cycle from egg to adult in approximately one month. Even this temperature appears to be below the optimum. Kawano (8) gives the optimum as 89·6–93·2°F. (32–34°C.), and in preliminary experiments we have found that breeding is more rapid and prolific at 95°F. (35°C.) than at 90°F. Breeding still takes place, though on a reduced scale, at 100°F. (37·8°C.). It is of interest to note, in this connexion, that neither species of *Calandra* will breed in wheat at temperatures of 95°F. or over.

On the descending scale, the important point is the temperature at which development ceases. This probably lies between 70·F. (21·1°C.), which temperature Dendy and Elkington (9) considered the lower limit for multiplication, and 59°F. (15°C.) at which temperature Kawano (*loc. cit.*) states that *Rhizopertha* appears unable to breed.

Although the resistance of *R. dominica* to low temperatures appears to be slight (Kawano found that adults survived for three months only at 50°F.), it is very tolerant to high temperatures. Frappa (10) stated that it could be killed by an exposure of 3 minutes to a temperature of 122°F. (50°C.), but Dendy and Elkington obtained only 3 per cent. mortality after exposing adults for 3 minutes to 129–131°F. (54–55°C.), and as they did not obtain 100 per cent. mortality with a temperature of 143–145°F., they concluded that in

order to achieve a complete kill of *Rhizopertha* with a 3-minute exposure, a temperature of about 146°F. (63·3°C.) would be required. (According to Winterbottom, the heat sterilizing plants used during the last war period raised the grain to a temperature of 135–140°F.)

The moisture requirements of *Rhizopertha* appear to differ markedly from those of the true grain weevils. Dendy and Elkington were the first to show that this insect resists dry conditions much better than either of the two species of *Calandra*. They found that *R. dominica* was able to breed in wheat with an original moisture content of 6·1 per cent., whereas in such wheat adults of *C. granaria* and *C. oryzae* died without breeding. We have placed *Rhizopertha* in wheat at 8, 9, 10, 11, and 12 per cent. moisture content. Breeding took place in all cultures, and increased in extent with increasing humidity; but whereas the difference between the rate of breeding at 8 per cent. and 9 per cent. moisture content was marked, comparable increases were not obtained in the higher range. The response of *Calandra* to increasing grain moisture is very different. In both species the breeding rate has been found to increase substantially with each increase of 1 per cent. in grain moisture up to the limit studied, i.e., 14 per cent.; and the insects will breed readily in grain so moist that rapid and heavy mould growth takes place. We have found that *C. oryzae* does not breed in grain with 10 per cent. moisture or less, though *C. granaria* can tolerate somewhat drier conditions. One recent observation of *Rhizopertha* in the field tends to confirm the conclusion, based on laboratory studies, that this species may habitually infest drier grain than the true wheat weevils. Whereas we have come across no instance of serious infestation by *C. oryzae* or *C. granaria* in grain that was not known, or suspected on very good grounds, to be well above 10 per cent. moisture content, samples of wheat taken from points within an inch or two of a flourishing *Rhizopertha* infestation in a Western Australian bin were found to contain less than 8·5 per cent. moisture.*

A point of interest in connexion with *Rhizopertha* (which has been commented on by Dendy and Elkington and by Potter, and has been apparent in our own experience) is that even with heavy infestations in a relatively humid atmosphere, the wheat in which this species has bred and fed rarely becomes mouldy. This suggests that *R. dominica* does not raise the moisture content of grain by its activities to the same extent as do the two species of *Calandra*.† Some recent observations by Dr. J. S. Fitzgerald, of this Division, lend confirmation to this conclusion.

Light has been thrown on the peculiar destructiveness of *Rhizopertha*, which has attracted the notice of most observers, by the results of some experiments that have been carried out in collaboration with a colleague, Mr. T. Greaves. It was found that whereas adults of *C. oryzae* ate or destroyed approximately their own weight of wheat in a week, adults of *R. dominica* destroyed five to six times their weight in the same period. Microscopic examination of the "dust"

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* These samples were taken, and their moisture content determined, by an officer of Co-operative Bulk Handling Ltd., Perth.

† It has been shown by experiments carried out at Canberra (see Ratcliffe, Gay, and Fitzgerald, 1) that *Calandra* can raise the moisture content of wheat it infests by as much as 5 or 6 per cent. in eight weeks.

produced by *Rhizopertha* indicates that the greater part of it is merely pulverized grain, and not excreta. The tendency of this insect to gnaw away much more of the interior of grains than is necessary to provide it with food is probably a relict of its ancestral wood-boring habits.

IV. Present Position and Probable Future Developments.

Queensland and New South Wales.—The position in these States has already been referred to. The officer of the Queensland Department of Agriculture, who is keeping the Darling Downs stacks under observation, has not reported *R. dominica* as being abundant. In New South Wales we know that the insect is present in the wheat belt, and is liable to appear in parcels of bagged wheat. We suspect that it is the most important pest of bulk wheat in this State, though information as to the relative status of the different primary pest species in the country and terminal silos is lacking.

Victoria.—A few bags infested with *Rhizopertha* were discovered recently in a stack at Williamstown (and dealt with); but, apart from this, we have no information of the occurrence of *R. dominica* in this State at the present time.

South Australia.—After having been officially unnoticed since the 1917-19 weevil plague, *R. dominica* recently made its appearance in the bagged wheat stacked along the dock at Port Pirie. We have also been informed that some bags in the Kadina depot, in which 1939-40 wheat is stored, have been found infested by this species. We understand that the Port Pirie infestation is described in an article by Mr. D. C. Swan in the August issue of the *Journal of Agriculture of South Australia,* which is not available at the time of writing. One of us (F.N.R.) has examined the Port Pirie infestation, and found *Rhizopertha* beginning to infect stacks all along the wharf. In two stacks only (which were probably the source of the spreading trouble) did the infestation appear to have gone beyond the very earliest stage, in which the entry points of what seemed to be single insects into odd bags here and there on the stack faces could be seen.

Western Australia.—One of us (F.N.R.), in a recent visit to this State, had the opportunity, through the co-operation of the local bulk-handling authorities, to obtain a reasonably comprehensive picture of existing conditions. *Rhizopertha* was seen in a number of bins and bulkheads in the country, scattered over the greater part of the wheat belt, and also in the wheat stored at Fremantle. In one or two instances this species was found (generally associated with *Calandra*) in infested "pockets" of grain situated near the floor or walls of bins; but the majority of infestations seen were confined to the surface layers of the wheat.* They varied in depth from 1 or 2 to 12 inches, and occasionally extended over the greater part of the available surface of the grain in a small bin. With very few exceptions, the infestations seen were in bins containing 1939-40 wheat, which had, at the time, been in store for about eighteen months. Evidence was obtained that the surface infestations tended to be localized directly above hot layers or pockets

* A silo attendant in New South Wales, when shown specimens of *Rhizopertha*, informed us that he had seen this "weevil" in one of the bulkheads established in this State in 1940. The infestation was localized on the surface, and was remarkable for the amount and whiteness of the dust associated with it.

in the grain. According to officers of Co-operative Bulk Handling Ltd., *Rhizopertha* was a relatively unimportant pest until a year or two ago; that is to say, the occurrence of troublesome outbreaks of this insect coincided with the termination of normal handling conditions, under which any grain showing signs of infestation or excessive heating could be cleared without delay, leaving the affected bins or bulkheads empty for part or all of the winter. Since 1939 it has not always been possible to clear grain when desired; wheat of successive crops has overlapped in storage in many sidings; and sometimes it has been necessary to receive wheat at a siding where there was already a well-established infestation.

The observations that have been made on the occurrence of *R. dominica* since the outbreak of the war, and the consequent dislocation of shipping and interference with the normal clearance of wheat, have been in line with what might have been expected. Knowing the insect's high temperature requirements and its apparent ability to develop in fairly dry grain, one would expect serious infestations to appear first in bulk wheat, which, because of its liability to heat, can provide favorable conditions for the multiplication of this pest throughout the twelve months of the year. The development of infestations in bag stacks from the odd individuals which will have found their way into the grain, at least in certain areas, would be very much slower. Moreover it is possible that in the case of wheat held in cold districts, such as Spring Hill, the slight original infestation which might have been included in the stacks would have died out altogether. (As *Rhizopertha*-infested bags were rejected from the Spring Hill depot, it is safe to assume that a few insects must have been in the wheat that was stacked there.)

Regarding the prospects for the future, the fact that Australia is handling and storing much of its wheat in bulk will obviously favour *Rhizopertha;* and there seems little doubt that it will far outdistance the *Calandra* species as a pest of bulk grain, since such grain is very largely protected from any substantial moisture build-up, such as normally takes place in stacked bagged wheat. Unless conditions comparable with those that occurred during 1917-19 develop—and there is reasonable hope that this can be avoided—*Rhizopertha* should not prove such a serious pest of bagged wheat as it did in the last war.

The bulk-handling States—at any rate, Western Australia and New South Wales—will face the difficult period starting with the 1941 harvest (little of which is expected to be exported during 1942) with *Rhizopertha* well-established and widespread. The fact that the actual loss caused by this pest in wheat stocks to date has been relatively insignificant does not mean that serious trouble is unlikely to occur in the future; for if favorable breeding conditions and facilities for cross-infestation between parcels of grain in storage occur, as they must in some measure, the build-up of populations of *Rhizopertha* to plague proportions may be very rapid.

Regarding the prospect of control, it is encouraging to know that *Rhizopertha* has been dealt with effectively in a concrete silo by fumigation with Cyanogas (see Fitzgerald, Ratcliffe, and Gay, 7) A more recent investigation, the results of which have not yet been published, has indicated that carbon bisulphide could be used with

good effect to treat localized "surface" infestations of this insect. A satisfactory method of dealing with general, as opposed to localized, infestations in bulkheads and bins of the Western Australian type has yet to be developed.

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Yellow Dwarf of Tobacco in Australia.

II. Transmission by the Jassid *Thamnotettix argentata* (Evans).

*By A. V. Hill, M.Agr.Sc.**

Summary.

In a tobacco field, in two successive seasons, plants protected from insect attack remained healthy. If grafted with scions from diseased plants they developed yellow dwarf. Unprotected plants became diseased.

The jassid, *Thamnotettix argentata* (Evans), is a vector of yellow dwarf, a virus disease of tobacco in Australia. The minimum incubation period of the disease in the plant is ten days.

1. Introduction.

Yellow dwarf of tobacco† occurs in Victoria, New South Wales, Queensland, and South Australia, but causes most loss in Victoria and in some districts of New South Wales. Field studies on occurrence and distribution of the disease were made, mainly in Victoria, during the seasons 1937-38 to 1940-41. These showed that cultural practices were seldom, if ever, effective in reducing the percentage of diseased plants. The extent to which the plants were dwarfed by the disease varied, especially with seasonal conditions, but the distribution in the fields in different seasons, locations and stages of growth, was of the same type. This evidence and the results obtained in large and relatively insect-free cages in fields indicated the presence of an insect vector, a conclusion confirmed by the results of the experiments reported in this paper.

2. Experiments in Tobacco Fields.

The object of these experiments was to investigate the effect of exclusion of insects on the occurrence of yellow dwarf under field conditions. Complete exclusion of insects was not obtained, but the non-occurrence of yellow dwarf in the protected tobacco plants indicated that the vector of the disease was excluded.

In a tobacco field at Shepparton,‡ Victoria, an area measuring 27½ feet x 6 feet was enclosed with butter-muslin supported on a wooden frame to form a plant house 6 feet high. The butter-muslin weighed 13½ lb. to the roll of approximately 120 yards 3 feet wide, and had 56 warp threads and 44 weft to the inch. On 16th November, 1937, 60 tobacco seedlings were planted in the soil in the area enclosed by the muslin, there being three rows 20 inches apart, and 15 inches between plants in the rows. The seedlings were grown at Eurobin, N.E. Victoria, in a seedbed in which benzol was used for the prevention of downy mildew. They were of two varieties, Dungowan and Dungowan

* Pathologist, Division of Plant Industry.

† See this *Journal* 10: 309-312, 1937.

‡ The hot, dry climate at Shepparton is relatively unfavourable to downy mildew (blue-mould), an important consideration when continuity of experimental work on other diseases is desired, and for this reason most of the insect transmission experiments reported herein were made there.

Selection; half of the 30 plants of each variety were grown under organdie to exclude insects throughout the seedling stage. Similar lots of seedlings were planted adjacent to the cage. The tobacco field was planted on 30th November.

On the 8th January, 1938, all the plants grown under cover were healthy, but eight of the 60 check plants just outside were affected with yellow dwarf. The proportion of diseased plants was slightly greater than in the adjoining field crop. Yellow dwarf scions were then top-grafted to twelve apparently healthy plants in the plant house. Twelve other plants were topped to the height of the grafted plants. Subsequently, all the grafted plants developed typical symptoms of yellow dwarf, but all the ungrafted plants remained healthy. Forty-six days after grafting, the butter-muslin cover was removed and all plants were cut off near the ground level. New shoots that developed from the bases of the twelve grafted plants showed yellow dwarf symptoms, but those on all other plants formerly under cover were healthy. The check plants were cut off in a similar manner, and symptoms of the disease occurred in the new shoots of two plants additional to those that had obvious yellow dwarf symptoms at the time they were cut back.

In a similar experiment at Gunbower in the following season (1938-39) all the plants were of the variety Hickory Pryor and were from open seedbeds in the Gunbower district. On the 4th January, 40 days after transplanting, all plants in the area enclosed by butter-muslin were healthy, but 43 per cent. of the controls in the adjacent field were affected by yellow dwarf. Scions from diseased plants were top-grafted to twelve of the plants under cover and twelve others were topped to the height of the grafted plants. All grafted plants developed symptoms of yellow dwarf. At the termination of the experiment, the average height of the twelve diseased plants was $3\frac{1}{2}$ feet, whereas that of the 48 healthy plants was 6 feet.

3. Transmission Experiments.

(*a*) *At Shepparton, Vic.*, 1939-40.

In October, 1939, a temporary field station was established at Shepparton. In two plant houses, each with a roof of windowlite,* walls of butter-muslin, and baffle entrances, space was available for a total of 850 six-inch pots. Insect-free tobacco plants were grown for use in transmission tests with four species of jassids, two species of plant bugs, and one of aphis. Mass collections were made of all insects occurring in tobacco fields where yellow dwarf was present or was thought likely to affect a high percentage of plants. Each species suspected of being a vector was then removed separately and placed in organdie or butter-muslin cages measuring 30 inches x 30 inches x 20 inches high. In these cages were placed insect host plants other than tobacco, several yellow dwarf tobacco plants, and a number of healthy tobacco seedlings. At varying intervals the apparently healthy tobacco plants were removed to an insect-free plant house, their places being taken by other healthy tobacco plants. New collections of insects were added to the respective cages from time to time, but as the mortality, particularly of *Thamnotettix argentata*,†

* Windowlite is a proprietary glass substitute.

† *Thamnotettix argentata* (Evans) is of the family Euscelidae and is described by Evans in *Pap. and Proc. Roy. Soc. Tas.*, p. 15, 1938.

the most numerous of the insects collected, was high, the concentration of insects was never excessive. Experiments were begun on 1st November, and were continued until the 24th January, 1940, the final observations being made on 8th March.

Altogether, 173 plants were placed in cages with various insects, other than the jassid *T. argentata,* collected from a tobacco field in which 95 per cent. of the plants were affected with yellow dwarf by the end of December. None developed symptoms of the disease, nor did any of the 150 plants kept in other insect-free cages (Table 1).

Three cages were used for transmission experiments with the jassid *T. argentata.* In the first and second cages in which 15 out of 53 plants and 14 out of 48 plants, respectively, became diseased, all the jassids used were collected in a diseased tobacco field. In the third cage, in which 7 of the 29 plants became diseased, the vector was collected near the lights of a motor car at Shepparton during a mass flight of *T. argentata* on the evening of the 4th January, 1940 (Table 2). In another cage were placed all species of insects collected with a net at various times in a tobacco field. Ten of the 34 plants placed in this cage developed yellow dwarf.

The minimum period for the development of symptoms in plants exposed to *T. argentata* in cages or in the field was ten days. This is about half the time taken under greenhouse conditions for transmission by grafting.

(*b*) *At Canberra,* 1940.

On the 25th January some of the *T. argentata* used in the transmission tests at Shepparton were transferred to Canberra and placed on several host plants in a breeding cage in the greenhouse. In September, when new adults were numerous, and possibly a few of the original adults still survived, some of the jassids were transferred from the breeding cage to healthy tobacco plants. Of the 48 tobacco plants placed in small cages with *T. argentata,* 15 subsequently developed yellow dwarf. The disease did not occur in insect-free control plants.

(*c*) *At Shepparton,* 1940-41.

Transmission experiments were begun on 29th October with *T. argentata* collected at Nathalia and were continued until 25th February, 1941, with collections made during that period. Usually the jassids were obtained by sweeping the selected area with an insect net in the morning, transferring the catch to an insect cage, then using a suction tube to select the species required. They were then transferred directly to healthy tobacco plants. Jassids obtained from various host plants growing naturally in several localities were used in these tests. Organdie bags measuring approximately 15 inches by 12 inches were used as cages in the transmission tests. They were inverted over healthy tobacco plants and were supported from the inside by two wires with ends pushed into the soil of the 6-in. pot, the mouth of the bag enclosing the top of the pot. After the jassids were transferred from the collecting tube to the bag, it was tied securely. About ten days later, the bag was removed, the surviving jassids collected, and the plants sprayed with a mixture containing nicotine sulphate and white miscible oil before removal to an insect-free plant

TABLE 1.—YELLOW DWARF OF TOBACCO—INSECT TRANSMISSION EXPERIMENTS, 1939-40.

Period of Exposure of Tobacco Plants to Insects.	*Nysius vinitor* (Berg.) (Rutherglen Bug).				*Empoasca terrae-reginae* (Paoli.) (green jassid).*				*Erythroneura* sp. (a small greenish-yellow jassid).				*Crytopeltis Javana* (Popp.†) (Tobacco capsid).				Some of All Species Used in Other Tests.‡	
	Number of Plants.		Insects Added.		Number of Plants.		Insects Added.		Number of Plants.		Insects Added.		Number of Plants.		Insects Added.		Number of Plants.	
	Used.	Infected.	Date.	No.	Used.	Infected.	Date.	No.	Used.	Infected.	Date.	No.	Used.	Infected.	Date.	No.	Used.	Infected.
Nov. 1–Dec. 17 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	1
Nov. 19–Dec. 17 ..	4	0	Nov. 19 Dec. 3	50 70	4	0	Nov. 19 „ 29	10 8	5	0	Nov. 19	50	6	0	Nov. 19 Dec. 3	50 60	..	..
Dec. 14–Dec. 17 ..	..	..	..	..	6	0	Dec. 3 „ 14	92 154	6	0	..	..	6	0	Dec. 14	100	..	..
Dec. 14–Jan. 5 ..	6	0	Dec. 15 „ 22	4 100	..	..	..	..	..	..	..	..	..	..	..	..	10	5
Dec. 17–Dec. 22 ..	..	..	..	..	9	0	..	..	..	..	..	..	11	0	..	..	..	..
Dec. 17–Jan. 5 ..	..	..	..	..	..	..	..	..	9	0	..	..	..	..	..	..	..	..
Dec. 22–Jan. 5 ..	..	..	..	..	9	0	Dec. 22	275	..	..	Dec. 22	5	7	0	Dec. 22	20	..	..
Jan. 5–Jan. 12 ..	16	0	Jan. 6	12	12	0	Jan. 6	100	17	0	..	..	..	..	..	..	14	2
Jan. 12–Jan. 24 ..	17	0	Jan. 20	200	12	0	..	..	11	0	..	..	..	..	..	..	7	2
Totals ..	43	0	..	..	52	0	..	..	48	0	..	..	30	0	..	..	34	10

* The large green jassid *Eurinoscopus viridis* Ev. was also added to these plants—14 up to 14th December and 25 on 22nd December. Green aphis was present in this cage from 22nd December to 24th January.

† On 5th January these were transferred to the cage with *Nysius vinitor*.

‡ All insect species obtained by sweeping in a tobacco crop were added to this cage from time to time.

TABLE 2.—TRANSMISSION OF TOBACCO YELLOW DWARF BY *Thamnotettix argentata* (EVANS)—1939-40 EXPERIMENTS.

Period of Exposure of Tobacco Plants to Jassids.	Cage 1.				Cage 2.				Cage 3.			
	Number of Plants.		Jassids Added.		Number of Plants.		Jassids Added.		Number of Plants.		Jassids Added.	
	Used.	Infected.	Date.	Number.	Used.	Infected.	Date.	Number.	Used.	Infected.	Date.	Number.
Nov. 19–Dec. 17 ..	..	..	..	..	4	1	Nov. 19 ,, 29 Dec. 3	100 32 100	..	..	..	..
Dec. 3–Dec. 17 ..	5	0	Dec. 3 ,, 14 ,, 15	46 100 500	..	..	..	..	..	..	..	..
Dec. 14–Dec. 17 ..	6	4	..	..	6	0	Dec. 14 ,, 15	65 600	..	..	..	..
Dec. 17–Dec. 22 ..	9	3	..	..	9	1	..	..	..	..	..	..
Dec. 22–Jan. 5 ..	9	4	Dec. 22	500	9	5	Dec. 22	400	..	..	..	..
Jan. 5–Jan. 12 ..	15	2	Jan. 6	150	16	6	Jan. 6	200	12	4	5	800
Jan. 12–Jan. 24 ..	7	1	..	..	3	1	..	..	16	2	..	..
Jan. 17–Jan. 24 ..	2	1	..	..	1	0	..	..	1	1	..	..
Total ..	53	15	..	..	48	14	..	..	29	7	..	..

house. Altogether 626 plants were used in 149 transmission experiments with *T. argentata* collected from various host plants in different localities and at different times. Yellow dwarf occurred on one or all of the plants in each of 64 experiments in which 262 plants were used. The disease was transmitted to 121 of the 262 plants. Several hundred insect-free plants kept under similar conditions remained healthy. Both nymphs and adults of *T. argentata,* particularly those collected during the month of November, transmitted yellow dwarf.

The appearance of *T. argentata* in large numbers in tobacco crops occurs as a result of a migration induced by the drying up of the winter and early spring host plants. This usually occurs late in November, but in the 1939-40 season transmission experiments and field occurrence of the disease showed that viruliferous jassids were most numerous during the latter half of December. Many attempts to breed *T. argentata* on tobacco have, so far, failed. Nor have nymphs been found on tobacco in the field. In the absence of more suitable host plants heavy mortality occurs; consequently, after the spring migration of the vector is completed, tobacco plants are seldom infected with the virus.

Obtaining Virus-free Potatoes.

By J. G. Bald, M.Agr.Sc., Ph.D., and D. O. Norris, B.Sc.Agr.**

Summary.

Two attempts have been made to obtain potatoes of the variety Up-to-Date (Factor) free from all virus diseases, particularly from virus X, which was reported to be present in every plant of this variety. In the first attempt one tuber free from virus X was obtained, but it was found to carry the virus of leaf roll. At the second attempt tubers were found which appeared to be completely virus-free.

In Australian potatoes, the virus diseases that are the most obvious causes of loss are due to three viruses. These are transmitted in the field by aphides, and are commonly known as A, Y, and the virus of leaf roll. There is a fourth which appears not to be disseminated by insects at all, but by the rubbing together of the foliage of diseased and healthy plants. It was once known in America as the "healthy potato virus", because it was found in all apparently healthy plants of the commonly grown American varieties. It is now most widely known as virus X, or, in Kenneth Smith's nomenclature (5), as Solanum virus 1. Because of its unobtrusiveness it was often claimed to be of little or no importance, but in recent years it has been found to cause losses in yield of 20 to 30 per cent. These figures have been obtained in Scotland (1) and Australia (3) from field trials with different varieties grown under widely different conditions.

In Australia (2) as in America the great majority of potato varieties carry virus X. It is safe to assume that well over 90 per cent. of the potatoes grown in Australia are infected, and a simple computation will show that, if this virus were eliminated from all potato stocks, the yield would be so increased that the normal production of Australian requirements would be satisfied by planting about four-fifths of the present acreage to potatoes. Such simple feats of arithmetic are often deceptive, but the conclusion is inescapable that the losses from virus X are at least as serious as the losses from all other virus disease combined, and, in terms of money, they may reach a figure of something like £350,000 per annum.

A realisation of these possibilities led one of the authors (J.G.B.) in 1936 to attempt the task of finding a virus-free potato of the principal New South Wales variety, Factor (Up-to-Date). A bag of tubers was obtained from a grower of certified seed in the Crookwell district, and after sprouting, 500 tubers were chosen for indexing. An eye was cut from each and planted in a bed of sand in a greenhouse. The index pieces were watered with culture solution. A week later the 500 tubers from which the eyes had been taken were planted in the field. As the index pieces grew, small pieces of leaf tissue were taken from them, and inoculated to various hosts such as *Datura stramonium,* which respond to most strains of virus X with a mottle. In this way all the 500 were indexed. Inoculations from a few of them failed to give a response, but, on further testing, all except

* An officer of the Division of Plant Industry.

one were shown to contain mild strains of virus X which produced symptoms only on two of the hosts used, Epicure potato, and pepper. One plant appeared to be free from virus X. This plant in the field was protected from infection by pulling up all others near it.

It was harvested early, and bore thirteen tubers. These sprouted during June, 1937. They were planted in pots in the greenhouse, and inoculations were made from them to President and Epicure potato plants. None caused symptoms. Many subsequent inoculations to various hosts gave negative results, and any Factor plants from this stock that were inoculated with virus X readily became infected. Plants merely coming in contact with other potato plants containing virus X also in a number of instances became infected. This proved that the Factor did not carry a mild strain of virus X. Final proof was obtained from the negative results of serological tests, kindly performed by Mrs. Mushin at the Botany School, University of Melbourne.

However, although this stock was free from virus X, it was found to be infected with leaf roll virus. The reason why the infection with leaf roll was not observed at once was that the symptoms of leaf roll in the absence of virus X are unusually mild in this variety, and conditions were unfavorable for diagnosing the disease. When the presence of leaf roll was once suspected, it was soon proved to be present in the whole stock.

Another attempt to find a virus-free Factor was begun in 1940 with two bags of tubers obtained from a grower of certified seed in New England. There were 960 tubers in the two bags. Over a period of several months inoculations were made from each tuber to pepper or Epicure potato plants. By the end of November, 1940, there were still 28 plants which had caused no reaction; the remainder were proved to contain virus X. While preparations were being made for the final tests, half of each of the 28 tubers were sent to the grower from whom the original tubers had been obtained, to be planted at double width in a plot on his farm, so that they would grow without the risk of contact between the foliage of adjacent plants. A similar plot was planted with the other half-tubers in isolation at Uriarra, about 20 miles from Canberra.

During the period when the inoculation tests were being performed, a single eye was cut from each tuber and planted in a pot in the greenhouse. Examination of these plants showed that several from the 28 tubers that had not been proved to contain virus X exhibited symptoms of leaf roll, others had faint but unmistakable symptoms indicating the presence of virus X. Some index pieces from among the 28 produced plants that looked completely healthy. The examination of the index pieces, and another series of inoculations eliminated all but thirteen tubers; these thirteen continued to give negative results from inoculation tests.

In February, 1941, the plants in the New England isolation plot were submitted to a detailed examination by Mr. Orman, Senior Agricultural Instructor, New South Wales Department of Agriculture. The notes made at this inspection were kindly forwarded to Canberra after notes had been made on the thirteen supposedly virus-free plants in the Uriarra isolation plot (all the rest had been rogued as soon as proof was obtained that they were not virus-free). In Mr. Orman's notes,

of the thirteen plants chosen as virus-free, eleven were recorded as "normal" or "normal and vigorous", one as very faintly mottled, and one as weaker than the majority. Of the seventeen discarded, none was recorded as normal, four had failed to sprout or been removed on advice from Canberra, four others were small or weak, and seven were faintly mottled.

In the isolation plot at Uriarra no evidence of virus infection was seen on the thirteen plants. Any abnormalities of growth observed were found to be associated with *Rhizoctonia* or the incidence of waterlogging, which occurred in one section of the plot after heavy rain. The yield was excellent, in spite of the poor soil in which the plants grew, even taking into account the wide spacing and absence of competition. Six completely normal plants yielded an average of 12·5 tubers weighing 4 lb.; 90 per cent. were of marketable size. Three plants affected with *Rhizoctonia* growing amongst these six had an average yield of 2 lb. 2 oz. (94 per cent. of marketable size), and the average of four waterlogged plants was 12 oz. (80 per cent. of marketable size).

Final tests for the absence of virus X were made on the progenies of index pieces grown in the greenhouse. Five of the plants supposed to be virus-free, and one free from virus X but infected with leaf roll were represented. The progenies were grown in the greenhouse, controls were set aside, and each remaining plant of a progeny was inoculated on the lower leaves with an isolate of virus X. Three isolates were used: one was almost a pure necrotic strain, the others contained predominantly severe and medium strains. After six days, numerous necrotic local lesions appeared on the leaves inoculated with the necrotic strain, later smaller necrotic lesions appeared on the leaves inoculated with the severe strain. Systemic symptoms characteristic of the strain of virus X inoculated, developed on the younger leaves. Control Up-to-Date plants containing a mild strain of virus X gave no reaction to inoculation with the necrotic strain.

These results were confirmed by other experiments. There is no doubt that most, and probably all the thirteen Factor plants chosen as virus-free are free from virus X. The healthy appearance of plants growing under good conditions and the high yield they have produced in an infertile soil encourage the belief that at least ten of these plants are entirely free from virus infection. They form the possible basis for a stock which could in time replace the infected stocks at present grown, and reduce the losses caused in this variety by virus X.

The work that must be done before this can be accomplished is considerable. The mere multiplication of the stock to supply seed for the present Australian acreage planted to Up-to-Date and Factor is unlikely to take less than six years. Other problems have to be faced. Firstly, what are the agronomic qualities of the virus-free plants? They may be inferior or superior to those of the stocks ordinarily grown, and there may be strains with different characteristics among the thirteen plants chosen. To test this, single plant progenies will have to be maintained separately and tested for yield, maturity, quality, and other significant attributes. Above all, they will have to be maintained free from infection with virus X. This means the maintenance and constant testing of a virus-free nuclear stock, and strict control

of its multiplication. The most essential feature during multiplication will be isolation from crops containing virus X. Fortunately, virus X does not appear to be transmitted by insects, and actual contact with other potatoes or weeds carrying the virus is generally the means by which the virus is spread. On the other hand, other agents might easily carry infection, e.g., the knife used to cut seed tubers, and possibly even the hands or clothes of farm workers coming in contact first with diseased and then with healthy plants.

In spite of such possible agents of dissemination, it has been proved in Ireland (4) that the multiplication of potato stocks free from virus X is practicable under farming conditions. If the virus-free Factors obtained during the work described in this paper are found to give a better yield than infected strains, and to have other necessary agronomic characters, there is no reason why they should not be multiplied and reach the farmer in almost as healthy a condition as they appear to be at present. The organization for handling them would need to be strict, but the cost need not be great.

The finding of virus-free Factors raises one more question: may there not be similar virus-free plants of other varieties which could be isolated in the same way? Quite likely there are. Indications have been obtained that virus X does not infect every plant of the varieties Carman, Bismarck, and possibly Western Australian Delaware; and a careful search might reveal plants that are free, not only from virus X, but from all other viruses as well. It is intended that this search will be undertaken in the near future.

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An Examination of Some Australian Hardwood Charcoals with Special Reference to their Suitability for Charcoal Gas Producers. Part II.*

By Enid C. Plante, B.Sc.†

Summary.

1. A commencement has been made with laboratory work to determine the optimum conditions for carbonization of Australian hardwoods. Destructive distillation of River Red Gum has been undertaken at maximum temperatures of 600°, 450°, and 350°C. respectively, and the charcoal produced examined by standard methods.

2. Examination and analysis of charcoals produced from Australian timbers have been continued, using various Queensland timbers. The prevailing view that certain northern timbers give charcoal of high ash content has been confirmed.

3. A method is outlined for the determination of the "tar content" of charcoal. It is emphasized that mere specification of a maximum tar content of charcoal may be insufficient; it is the tar content of the producer gas itself that matters.

1. Experimental Carbonization of Timbers.

Experiments on the carbonization of different timbers were commenced with three aims in view—

(i) To ascertain the optimum carbonization temperature for "producer charcoal"; this obviously depends on the time of carbonization.

(ii) To determine whether any particular Australian woods are especially suitable or unsuitable.

(iii) To obtain charcoals which have been carbonized under known conditions—these charcoals to be used in the examination of the volatile content, tar content, and other important chemical and physical characteristics of charcoal.

A comprehensive research programme was planned at the outset, but for various reasons much of the projected work remains uncompleted. The timber, cut into prisms 1 in. x 1 in. x 18 in., was to be carbonized at temperatures of 300°, 350°, 400°, 500°, 600°, and 700°C. in a small experimental retort in an electric furnace, the internal and external temperatures of the charge being recorded. Time permitted work at only three of these temperatures.

It should be noted that mere specification of maximum temperature is not sufficient to describe the conditions of formation of charcoal. The temperature must be slowly raised to the maximum, and then maintained constant for a specified period. Even then equilibrium is not reached, although after three hours the speed of reaction is negligible, and in the experiments described this period was adopted.

* Part I. of this investigation was published as Coun. Sci. Ind. Res. (Aust.) Pamph. No. 103 (1940).

† An officer of the Division of Industrial Chemistry.

The initial work was carried out on one timber, viz., River Red Gum. It was hoped that the various charcoals would be tested in the producer and that the tar content and calorific value of the gases produced would be determined.

Experimental.

Three distillations have been carried out on River Red Gum (*Euc. rostrata*) at maximum temperatures 600°C., 450°C., and 350°C. respectively. Results are set out in Table 1. As might be expected, the yields, densities, and volatile and tar contents of the charcoals vary inversely with the carbonization temperatures. The calorific value, however, varies directly with the carbonization temperature. The charcoal obtained at 600°C. simulated commercially-burned kiln charcoal in its properties most closely of the three; the other two samples were very hard and presented a more shiny fracture than is common with commercial charcoal. During the distillation, the volatile matter was led off from the retort, and copious heavy gaseous fumes were evolved; much condensible tar condensed under water.

TABLE 1.—EXPERIMENTAL CARBONIZATION OF WOOD.

——	River Red Gum (1).	River Red Gum (2).	River Red Gum (3).	Scented Satinwood.
(1) *Details of Experiment.*				
Maximum distillation temperature	600° C.	450° C.	350° C.	300° C.
Total period of distillation	12 hours	6–7 hours	22 hours	
Period at maximum temperature	3 hours	3 hours	3 hours	
Weight of wood distilled (1" x 1" x 18" prisms)	27·5 lb.	25·0 lb.	24·5 lb.	
Moisture content of wood	14·4 per cent.	13·9 per cent.	14·8 per cent.	
Weight of charcoal obtained	9·0 lb.	10·0 lb.	9·8 lb.	
Percentage yield of charcoal (dry-wood basis)	38·4 per cent.	46·5 per cent.	46·7 per cent.	
Specific gravity of charcoal	0·51 g./cc. (31·9 lb./cu. ft.)	0·55 g./cc. (34·4 lb./cu. ft.)	0·67 g./cc. (36·4 lb./cu. ft.)	
(2) *Proximate Analysis of Charcoal.* (Moisture-free basis).				
Moisture	1·78 per cent.	3·60 per cent.	2·78 per cent.	3·90 per cent.
Volatiles	9·5 per cent.	34·9 per cent.	35·8 per cent.	46·1 per cent.
Ash	0·50 per cent.	0·80 per cent.	0·29 per cent.	1·22 per cent.
Tar	0·07 per cent.	0·47 per cent.	0·87 per cent.	1·10 per cent.
Calorific value	14,730 B.Th.U./lb.	12,960 B.Th.U./lb.	12,130 B.Th.U./lb.	

Only the first two samples were burnt in the producer; both burned readily to give good quality gas, almost free from tar.

The analysis of a sample of Scented Satinwood charcoal (*Ceratopetalum apetalum*) carbonized by destructive distillation at a maximum temperature of 300°C., in the Forest Products Laboratory, is also given. The exceptionally high volatile and tar contents of this charcoal are due to the low temperature of carbonization. The charcoal was very hard and difficult to break and in places had the appearance of brown wood.

2. Analysis of Charcoal Samples.

(i) Six samples of charcoal from Queensland were analysed according to the Standard Specification; the results, expressed on a moisture-free basis, are given in Table 2.

The Dry River Red Gum (*Euc. rostrata*) passes the specification with regard to cleanliness, moisture, ash, and volatile content, although the ash content is higher than hitherto expected from *Euc. rostrata*.

TABLE 2.—CHARCOAL SAMPLES—ANALYSED ACCORDING TO STANDARD SPECIFICATION.

Charcoal.*	Percentage Dirt.		Results Expressed on Moisture-free Basis.				Appearance, Hardness, Friability of Charcoal.	Colour of Ash.
	After Drying.	After Ashing.	Moisture Percentage.	Ash Percentage.	Volatile Matter Percentage.	Calorific Value B.Th.U./lb.		
	%	%	%	%	%			
1. Bulloak (*Casuarina luehmanni*)	0·87	0·12	3·45	8·80	23·6	12,720	Hard, good fracture, fair amount of dust and fines	Light-grey
2. Boree (*Acacia pendula*)	0·74	0·10	5·50	7·53	15·5	12,910	Somewhat crumbly. Fair amount of dust and fines	Light-grey
3. Beefwood (*Stenocarpus salignus*)	0·52	0·24	3·70	9·67	17·4	13,490	Hard, good fracture. Little dust and fines	Light-grey
4. Brigalow (*Acacia harpophylla*)	1·59	..	5·25	7·70	16·4	12,710	Hard, fair amount of dust and fines	Light-grey
5. Sandalwood (*Santalum spicatum*)	0·31	0·03	6·12	7·32	12·2	13,660	Hard, little dust and fines	Light-grey
6. Dry River Red Gum (*Euc. rostrata*)	0·81	0·06	5·58	2·66	13·6	13,890	Good fracture, hard	Light-grey

* All samples of charcoal were from Queensland.

The other five samples, which are not Eucalypts, pass the specification with regard to cleanliness, moisture, and volatiles, but their ash contents, which are exceptionally high, fall outside the limit of the specification (3 per cent.). It is noticeable, although it may be merely coincidence, that all the charcoal samples from Queensland that have been analysed have higher than normal ash contents. The River Red Gum (*Euc. rostrata*) from Queensland has an ash content of 2·7 per cent., which is higher than that of *Euc. rostrata* from Victoria (0·64 per cent.) or New South Wales (0·91 per cent.). This higher ash content is not due to mineral matter derived from dirt, for this only amounts to 0·03 per cent., excluding the ash content. In addition to these five samples, Bulloak (*Casuarina luehmanni*), analysed previously (see Coun. Sci. Ind. Res. Pamphlet, No. 103), had an ash content of 4·54 per cent., which was higher than that of any other charcoal analysed, except Grey Box.

(ii) A series of analyses for moisture, dirt, ash, and volatile contents, and for calorific value, were carried out on Standard River Red Gum (*Euc. rostrata*). These analyses were made firstly in order to test the reliability of the analytical methods, and secondly in order to estimate

an allowable deviation in the figures obtained in analysing charcoal. Results (expressed on a moisture-free basis) are given in Table 3.

TABLE 3.—ANALYSIS OF STANDARD RIVER RED GUM CHARCOAL.*

	Moisture Percentage.	Per Cent. Dirt.		Ash Percentage.	Volatiles Percentage.	Calorific Value B.Th.U./lb.
		Before Ashing.	After Ashing.			
	6·74	0·787	0·04	0·919	10·9	13,250
	6·79	0·790	0·04	0·911	10·8	13,310
		0·813	0·05	0·925	10·8	13,010
		0·740	0·04	0·913	11·0	13,030
		0·815		0·904	10·6	
				0·907	10·8	
				0·907	11·1	
				0·922	11·0	
				0·919		
				0·907		
Average	6·75	0·789	0·04	0·913	10·9	13,150

* The columns in this table refer to independent series of analyses.

Further results are not given for the percentage moisture, as the moisture content of the charcoal varies daily, and the results obtained on different days could not be correlated.

(iii) An ultimate analysis of the Standard River Red Gum charcoal was carried out by Dr. Burger, of the Department of Chemistry, University of Adelaide. The charcoal was dried to constant weight at 105°C., and analysed for carbon, hydrogen, ash, sulphur, nitrogen, and halogen. Results are set out in Table 4. It is interesting to note that the charcoal contains small amounts of both sulphur and chloride; this may have some bearing on the corrosion effects sometimes experienced in the producer.

TABLE 4.—ULTIMATE ANALYSIS OF STANDARD RIVER RED GUM CHARCOAL.

—	Per Cent.
	%
Carbon	88·61, 88·66
Hydrogen	2·87, 2·96
Ash	0·85, 0·90
Sulphur	0·05, 0·05
Nitrogen	0·18, 0·17
Halogen (Cl)	0·06, 0·06

3. The "Tar" Content of Charcoal.

An attempt was made to develop a method for the determination of the amount of condensible volatile matter—commonly known as "tar"—present in charcoal. Such a test is not included in the Standard Specification for Wood Charcoal to be used in Producer Gas Vehicles.

The necessity for it has arisen from reports from users of producer gas that they have experienced trouble from "gumming" of valves, and that a number of units have been fouled on account of tar-like deposits. These deposits are due to condensible volatile matter which is carried over with the producer gas, and condenses on cooling.

The method of determination is to heat a known weight of charcoal —previously crushed to a uniform size—at a temperature of 950° in a slow stream of nitrogen, aspirate the gas stream through an asbestos filter which collects the condensible volatile matter, and determine the increase in weight of the filter, and hence the percentage of tar present. A temperature of 950°C. was chosen because the volatile content and reactivity of the charcoal are determined at this temperature. Although this involves some standardization, it leaves something to be desired, for the actual temperature in the producer is about 1,300°C. or higher. Theoretically, therefore, 1,300°C. would be a better temperature at which to carry out a test, but the practical difficulties would be greater. The temperature of 950°C. also permits correlation of the results with the volatile content, which may be estimated from the difference in weight of the charcoal before and after heating in the furnace.

In the method used for the determination of potential tar in anthracites, and fuels containing small amounts of tar, described by L. J. Edgcombe, of the Fuel Research Station (extract from Report of the Committee on the Emergency Conversion of Motor Vehicles to Producer Gas), the tests are carried out at 600°C. The temperature of the fuel is raised to 600°C. over a period of one hour and then maintained at that temperature for one hour. In order to compare the results obtained at 600°C. with those obtained at 950°C., three tests, summarized in Table 5, were carried out at 600°C. on charcoal identical with that which had been tested at 950°C.

TABLE 5.—COMPARISON OF "TAR" CONTENTS OF CHARCOAL AT 600° AND 950°C.

Charcoal.	Temperature of Distillation.	Per Cent. Tar by Weight.	Tar Content of of Gas.	Gas Evolved from Charcoal.
	Deg. C.		g./cu.m.	ml./g.
River Red Gum (I.)	950	0·07	3·2	220
Max. carbonization temp. 600° C. ..	600	0·01	4·0	36
Red Gum (II.)	950	0·47	14·5	330
Max. temp. 450° C.	600	0·46	3·0	190
Red Gum (III.)	950	0·87	22·9	380
Max. temp. 350° C.	600	0·22	8·8	250

Both the volume of gas evolved per gramme of charcoal, and the amount of tar obtained, are less at 600°C. than at 950°C.

It should be emphasized here that, although figures for the tar content can be obtained by this laboratory method, they will have little

significance unless they can be correlated with producer tests on the charcoal. Correlation may be difficult to establish. Thus reports indicate that trouble has been caused by tar from charcoal made from Bulloak (*Cas. luehmanni*) timber. When tested in the laboratory, this charcoal has a tar content of 0·08 per cent., whereas the Standard River Red Gum, which has been extensively used in producers, has a tar content of 0·06 per cent. and no trouble has been reported. Hence the next phase of this work should be tested in the producer, using the charcoal tested in the laboratory to determine whether the laboratory results obtained at 950°C. can be correlated with those obtained at the higher temperature of the producer.

Method.—The apparatus used for the test (see Fig. 1) is a modification of that used for determining the reactivity of coke, as described in the D.S.I.R. Fuel Research Technical Paper No. 18.

About 12 grammes of charcoal (accurately weighed), graded between 10 and 20 I.M.M., is packed in the central part (11 inches long) of a glazed silica tube, $\frac{3}{4}$ inch in diameter and 24 inches long. The charcoal is kept in place by means of two small asbestos plugs. The tube is placed in a horizontal electric tube furnace, about 12 inches long, with a tube diameter of $1\frac{1}{2}$ inches, and held in place by asbestos plugs. A slow stream of oxygen-free, dry nitrogen is passed across the charcoal, and the temperature of the furnace raised to 950°C. in about 50 minutes, the temperature being measured by a base metal thermo-couple, the tip of which is placed close to the central part of the silica tube.

Gas evolution usually commences at an indicated temperature of 200° to 300°C., which probably corresponds to a lower temperature in the fuel bed. The gases evolved, together with the nitrogen, pass through an asbestos filter into a 4-litre aspirator which receives the gas at atmospheric pressure. The furnace is maintained at 950°C. until gas ceases to be evolved from the charcoal. This period varies for different samples of charcoal, but generally ranges from 15 to 60 minutes.

Various filters were experimented with, and the most satisfactory was found to be a large porcelain Gooch crucible, in which was placed a small pad of cottonwool, covered by a layer of crude asbestos. This crucible is dried to constant weight in an air oven at a temperature slightly above 100°C. before and after use. The amount of tar present is estimated from the increase in weight of the filter, and the tar may be expressed either as a percentage weight of the charcoal, or as a certain weight per volume of gas evolved, the aspirator being graduated to enable the volume of gas collected to be measured. An average sample of gas is taken from the aspirator after thorough mixing, and analysed in a Harper apparatus, a modification of the Orsat apparatus which permits determination of the methane and hydrogen content of the gas. As derived from the charcoal, the gas consists chiefly of hydrogen, carbon monoxide, and nitrogen but it is diluted with the nitrogen used for aspiration. The added nitrogen can be measured, and the analytical results are corrected for it.

The "true" calorific value of the gas may be calculated from the gas analysis results for CO, CH_4, and H_2, using constants taken from Vol. I. of "The Internal Combustion Engine," by D. R. Pye, second

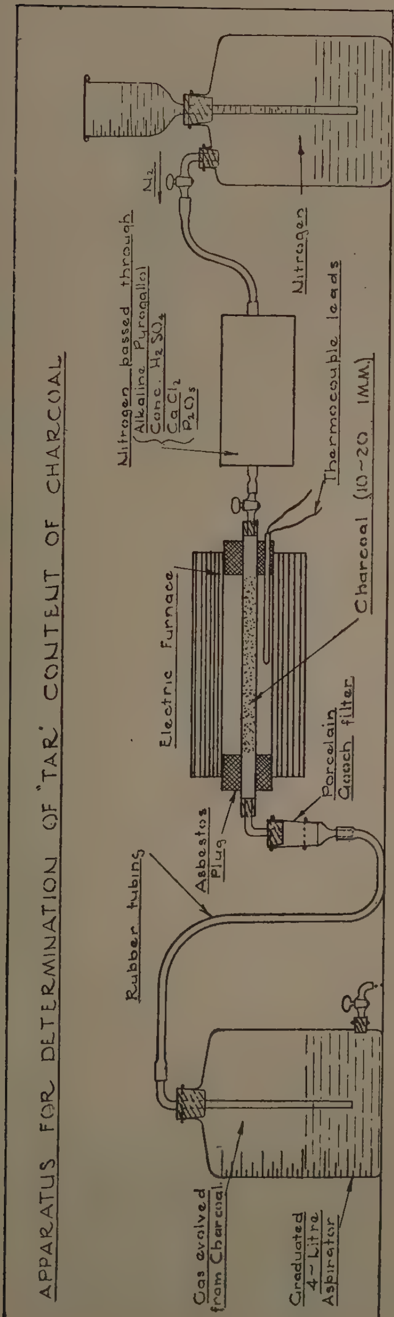
APPARATUS FOR DETERMINATION OF "TAR" CONTENT OF CHARCOAL
Nitrogen passed through
Alkaline Pyrogallol
Conc. H_2SO_4
$CaCl_2$
P_2O_5
N_2
Nitrogen
Thermocouple leads
Charcoal (10–20 MM.)
Electric Furnace
Porcelain Gooch filter
Asbestos Plug
Rubber tubing
Gas evolved from Charcoal.
Graduated 4-Litre Aspirator

Fig. 1.

edition, p. 285. The values are given by Pye in Centigrade heat units, and the corresponding values in B.Th.U's per standard cubic foot of gas are:—

Hydrogen	288
Carbon monoxide	338
Methane	961

The charcoal samples tested have been chiefly those whose analyses were given in the preceding paper of this series.* In addition, tests have been carried out on briquettes and on the River Red Gum, the carbonization of which in this laboratory is described above. It was hoped that, by testing a large number of samples, a figure for the percentage of tar allowable in charcoal might be reached, but, as has been stated, this cannot be done until the laboratory results are correlated with producer tests.

It appears that the tar content of the charcoal depends largely on the method of carbonization of the timber, and, more particularly, on the temperature of carbonization. It is difficult to obtain figures for this temperature, for most commercial burners do not measure it.

The results obtained from these tests are set out in Table 6. The volatile content of the charcoal and the volume of gas evolved per gramme of charcoal are given, and in certain instances analysis of the gas evolved is included. The samples are numbered as in Table 1 of the Council's Pamphlet No. 103.

No exact relationship appears to exist between the volatile content of the charcoal and the amount of condensible volatile matter, though it might have been anticipated that these two factors would be directly proportional. However, the three samples of charcoal carbonized at low temperatures, viz., Satinwood (290°C.), River Red gum (450°C.), and River Red Gum (350°C.), have the highest tar contents. One would expect that, in general, charcoal carbonized at low temperatures would have a higher tar content than that prepared at higher temperatures.

It is interesting to note the variation in the percentages of CO_2 and CO obtained by gas analysis for the different charcoal samples heated to the same temperature in an atmosphere of nitrogen. It is difficult to interpret these figures. It is probable that the reactivity of the charcoal both towards carbon dioxide and towards oxygen is important, but differential adsorption of gases may be more important.

It is also interesting to note the high methane values of the two River Red Gum charcoals carbonized at low temperatures, and also the high calorific value of the gas from every sample, due chiefly to the high hydrogen content.

It does seem desirable that a test for the determination of the condensible volatile matter or "tar" should be included in the Standard Specification for Charcoal, especially if there is no relationship between the tar content of charcoal and its volatile content. Whether the tar content should be specified for the charcoal or for the producer gas made from it cannot yet be decided. There is also the question of the relative amounts of dust and of "tar" obtained from the charcoal, and of how much tar is collected in the dust filters.

* Coun. Sci. Ind. Res. (Aust.) Pamph. No. 103.

TABLE 6.—DETERMINATION OF TAR CONTENT OF CHARCOAL FROM VARIOUS TIMBERS AND SOURCES.

Species.*	Volatile Content (Moisture-free Basis).	Tar by Weight.	Gas Evolved from Charcoal.	Analysis of Gas Evolved in Per Cent.						Furnace Maintained at 950° C. for—	Calorific Value of Gas.
				CO_2.	O_2.	CO.	CH_4.	H_2.	N_2.		
	%	%	ml./g.	%	%	%	%	%	%	Minutes.	B.Th.U./cu. ft.
3. Jarrah Saplings (*E. marginata*)	11·8	0·01	220	..	..	..	..	..	..	25	..
12. Standard River Red Gum (*E. rostrata*) ..	11·4	0·06	220	..	..	..	..	..	..	40	..
	..	0·06	210	3·1	..	24·1	2·3	49·0	21·5	20	244·5
14. Red Stringybark (*E. macrorrhyncha*) ..	5·7	0·16	180	..	..	..	..	..	..	45	..
17. Yellow Stringybark (*E. muelleriana*) ..	9·7	0·12	190	4·1	..	28·9	1·7	45·0	20·3	30	243·7
18. Messmate (*E. obliqua*)	7·3	0·12	310	3·8	0·5	32·2	..	..	..	30	..
19. Red Ironbark (*E. sideroxylon*)	16·3	0·04	260	3·2	..	26·3	1·6	26·0	42·9	45	179·1
21. Red Mahogany (*E. resinifera*)	15·8	0·03	190	..	..	..	..	..	..	40	..
22. White Mahogany (*E. acmenioides*) ..	21·0	0·04	160	7·6	..	26·8	1·5	27·3	36·8	50	183·4
22A. ,, ,, ,, ..	..	0·01	170	7·6	..	32·5	6·6	45·7	7·7	40	305·1
23. Grey Box (*E. hemiphloia*)	21·3	0·04	290	..	..	..	..	..	..	80	..
24. Yellow Box (*E. melliodora*)	10·1	0·02	140	..	..	..	..	..	..	10	..
25. Tallow-wood (*E. microcorys*)	3·7	0·07	130	..	..	..	..	..	..	10	..
27. Turpentine (*Syncarpia laurifolia*)	20·8	0·10	250	..	..	..	..	..	..	35	..
30. Bulloak (*Casuarina luehmanni*)	12·3	0·08	340	3·9	..	27·5	3·6	8·5	56·5	60	152·1
31. Timor White Gum (*E. alba*)	19·5	0·12	340	6·6	..	22·6	4·5	29·4	36·9	90	204·4
Tar pitch coke (carbonized at 500° C.) ..	4·13	0·08	270	0·3	..	2·6	2·7	86·0	8·2	20	282·8
Scented Satinwood (*Ceratopetalum apetalum*) (carbonized at 290° C.)	..	1·10	300	..	..	..	..	..	..	50	..
River Red Gum (*E. rostrata*) (carbonized at 350° C.)	35·8	0·87	380	2·9	2·9	27·0	11·2	33·6	22·4	70	295·6
River Red Gum (*E. rostrata*) (carbonized at 450° C.)	34·5	0·47	330	..	..	..	..	..	..	30	..
River Red Gum (*E. rostrata*) (carbonized at 600° C.)	9·5	0 07	220	2·0	3·3	9·7	9·6	69·0	6·4	45	223·7

* The numbers are identical with those of Table 1, Coun. Sci. Ind. Res. (Aust.) Pamph. No. 103.

It should be emphasized that the method described above for the estimation of the tar content of charcoal gives a measure of the tar in the charcoal and *not* in the producer gas. The temperature and thickness of hot bed, &c., for the producer itself will govern the rate and completeness of destruction of this tar. It might be desirable to attempt to devise a laboratory test using a miniature producer, in which temperature, &c., could be made identical with values in a normal producer, and to attempt to correlate the tar contents determined by the two methods. If correlation proved possible, one could revert to the simpler apparatus of Fig. 1.

Acknowledgments.

This work has been carried out by the author for the Council for Scientific and Industrial Research, which is sponsoring a programme of research upon the suitability of charcoal for use in gas producers. The author wishes to express her thanks to Professor Burstall, who has made available the facilities of the Engineering Laboratory for the work, and for the suggestions he has made regarding it.

The first section of the work, dealing with the carbonization of timbers, was carried out under the direction of Mr. B. M. Holmes, M.Sc., who was at that time an officer of the Council for Scientific and Industrial Research.

A Preliminary Investigation of the Yield and Composition of the Oil distilled from *Chenopodium ambrosioides* (Linn.) var. *anthelminticum* (Gray).

*By R. E. Shapter, A.A.C.I.**

Summary.

A preliminary investigation into the yield and composition of the oil distilled from *Chenopodium ambrosioides* var. *anthelminticum* grown near Adelaide, South Australia, and at Sydney, New South Wales, has been made.

The plants were collected when close to maturity, cured by air-drying, and subjected to a special method of steam distillation which was designed to give rapid distillation with as short a period of preliminary heating as practicable. It was not possible to distil the oil under ideal conditions, since steam under high pressures was not available. The method used, however, was satisfactory for making a preliminary investigation.

It was found to be best to remove the separated oil from the aqueous distillate when relatively small amounts of the latter had collected, in order to avoid losses by solution or emulsification of the oil.

Comparison was made of results obtained from several Australian-grown oils with an authentic sample as marketed by a well-known firm of essential oil manufacturers.

Results showed promise of satisfactory yields of oil being obtained from Australian-grown plants with ascaridole contents falling well within the amounts required by the British Pharmacopoeia. In other respects, the oils varied from the recognized standards. This however, may be of little importance, and oils produced in Australia may be found to have different constants from oils produced in America, which has been the chief source of production in the past.

The results of the investigation are favourable towards further inquiry into the production of the oil on a manufacturing scale. Further tests should be made using steam under high pressure for the distillation process. Inquiry into the effect of various methods of manuring and cultivation is also desirable.

The oil obtained from *Chenopodium ambrosioides* (Linn.) var. *anthelminticum* (Gray) appears in the British Pharmacopoeia (2) of 1932 as synonymous with Oil of American Wormseed. It is described therein as being obtained by distillation with steam from the fresh flowering and fruiting plants, excluding roots. In Thorpe's "Dictionary of Applied Chemistry" (5) the plant is stated to be a native of Central America and the West Indies. The commercial oil is said to be distilled chiefly in Maryland, United States of America, and is known as Baltimore oil. According to Weiland *et al.* (1) cultivation of the species has been carried out in Carroll County, Maryland, for more than 100 years. They state that, although the uncultivated forms of the plant occur almost throughout the entire United States, wormseed oil production on a commercial basis has been confined almost entirely to that region, and even within the county a small area of only about 8 or 10 miles diameter has been used for that purpose.

For many years the oil has been in use in the United States as an anthelmintic, but its appearance in the British Pharmacopoeia is comparatively recent. Its use is in the treatment of helminthiasis, in

* An officer of the Council stationed at the Waite Agricultural Research Institute, Glen Osmond, South Australia.

veterinary practice mainly against round worm (*Ascaris suilla*) in pigs, and in human beings against the round worm (*Ascaris lumbricoides*) and hookworm (*Ankylostoma duodenale*). The oil has to a large extent the same application as thymol as an anthelmintic, but has the disadvantage of being more toxic; by some authorities Oil of Chenopodium is regarded as being quite as effective as santonin (6) for worm treatment, although santonin is perhaps more specifically used in treatment of pin worms or thread worms (*Oxyuris vermicularis*). The use of Oil of Chenopodium is likely to be governed by its cost of production, price obtainable, relative effectiveness, and abundance compared with such drugs as thymol, which may be prepared either from the volatile oils of *Thymus vulgaris* L., *Monarda punctata* L., and *Trachyspermum ammi* L., or produced synthetically (2).

At present, owing to the prohibition of its importation from America as well as the possibility of shortage of santonin and thymol, the manufacture of Oil of Chenopodium in this country has become of some importance. The price of the oil has already risen considerably to three or four times its normal value. (A recent quotation was 5s. per oz. as against 1s. 9d. per oz. some months ago.)

Within the species *Chenopodium ambrosioides* the variety designated as *anthelminticum* appears to be unique in containing a high percentage of ascaridole, an aromatic compound having a peroxide structure which is related to cineol, a common constituent of many of the oils derived from the Eucalypts. It is to ascaridole that the effectiveness of the oil against intestinal worm infestation is ascribed. In Brazil, however, the oil from *C. ambrosioides* L. itself is said to be used as an anthelmintic (6). *Chenopodium* species are widely distributed and *C. alba*, ordinarily known as Goosefoot or Fat Hen, is a common garden weed, but *C. ambrosioides*, and more particularly the variety known as *anthelminticum*, is more rare. Owing to the probable shortage of supplies of Oil of Chenopodium and its recommendation by the Stock and Brands Department as an efficient anthelmintic for treatment of worms in pigs, a search was made by Mr. V. S. Luff of Kent Town, South Australia, to discover whether the anthelmintic variety of *Chenopodium* could be found growing in the wild state. Plants were found at Largs Bay,* and a large area extending from Outer Harbor to Brighton was further searched, specimens being collected for distillation of the oil and for seed. From some of the seed, plants were grown by Mr. Luff, and a plot of about half an acre was also planted at the Waite Institute.†

Plants grown by himself, and wild plants, were distilled by Mr. Luff, and the oil was forwarded to the Department of Agriculture for analysis.‡ From the plot at the Waite Institute a considerable number of plants were collected as a representative sample, and on these the present investigation into yield and composition of the oil was carried out.

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* Identification of the plants was confirmed by the well-known botanist, Mr. J. M. Black, and Miss C. M. Eardley, Curatrix of the Herbarium, University of Adelaide.

† Cultivation of the plants at the Waite Institute was under the control of Mr. C. A. N. Smith, an agronomist on the staff of the Institute.

‡ Analyses of these samples for ascaridole were made by Mr. S. D. Shield, Deputy Government Analyst at Adelaide, by courtesy of whom they are included in this report.

Just prior to the harvesting of the above plants at the Waite Institute, a sample of the flowering and fruiting tops of *C. ambrosioides* var. *anthelminticum* was received at the Waite Institute from the Botanical Gardens, Sydney, New South Wales. These were from wild plants collected in the grounds of the University of Sydney. This sample was treated as well as the sample from the Waite Institute.

The technique of distillation is important in producing a satisfactory yield of oil of high medicinal value. The stage of growth of the plants also appears to be of considerable importance and, according to Weiland (1), a curing process is necessary before distillation in order to ensure the maximum content of ascaridole, which is the chief constituent of the oil. It is claimed that an actual synthesis of ascaridole occurs during curing. Before cutting, the plants should be almost mature, but not so ripe that shattering of the seed will occur, since most of the oil is in the seed; the leaves of the plant and the lighter stems carrying the seed, contain less oil, and the main stems apparently little or none (1). Curing is carried out by simply air-drying the plant for several days before distillation (1).

The plants grown at the Waite Institute were harvested at the end of March, 1941, and the sample from Sydney, New South Wales, was received at the same time. The flowering and fruiting tops of both samples were almost mature. Most of the seed integuments were green but some were just turning light brown owing to drying off. The coats of the actual seeds after removal of the integuments were mainly in various shades of brown to glossy black, a small quantity being still geenish and soft.

The plants grown at the Waite Institute were cut off level with the ground, avoiding jarring and consequent loss of seed as much as possible. Since apparatus was not available for distillation of the whole plants owing to their large size, the fruiting tops and leaves were separated from the woody stems. The sample that was received from Sydney was quite fresh when received, and both samples were cured inside a room, out of contact with direct sunlight. The material was turned over daily until air-dry as determined by the stems becoming brittle and the seed able to be largely detached from the heads by shaking. Curing occupied about a week for the Sydney sample and about a fortnight for the sample collected at the Waite Institute, the second sample being considerably larger than the first.

Ascaridole is decomposed by overheating and prolonged heating, particularly in presence of water. For this reason authorities generally are in agreement that great care is necessary as to the technique employed in distillation (1, 5, 8). The latter operation must be carried out as rapidly as possible without any prolonged preliminary period of heating up from the cold (8). These conditions are obtained by avoiding the use of "pot" stills (8), or too large a reaction vessel in comparison with the capacity of the steam generator, by not adding water to the material in the reaction vessel, and by using steam at high pressure (80 to 100 lb.) (1, 7, 8). It is stated that the oil should all be distilled off within fifteen minues (1, 8) of starting distillation. A further difficulty is the tendency for the oil to dissolve or partially dissolve in water, and Weiland emphasizes the necessity for recovery of the dissolved ascaridole from the aqueous distillate. He states that ascaridole is soluble in water to the extent of 0.3 per cent. and that by

redistillation increased recovery to the extent of 15 per cent. can be made (1). It is further stated that the recovered oil is considerably higher in ascaridole that the original oil which is obtained by simple separation from the aqueous distillate (1). Indeed, it is claimed that practically pure ascaridole has been obtained by redistillation of waste liquors from distillation of the herb. Gildemeister and Hoffmann, however, are averse to any treatment which necessitates long contact of the oil with boiling water and recommend that stills of moderate size be used, and, in order to obtain a better separation of oil and water, that the condenser be allowed to run warm or even hot (1, 6, 7, 8). They state that the aqueous distillate then contains but little oil and is best thrown away, thus avoiding contamination of the product with inferior oil (6, 8).

Since no satisfactory method of distilling with steam under high pressure was available in the laboratory, the following procedure was adopted as an expedient which proved satisfactory as an experimental method, suitable for a preliminary investigation. A very large flask (12-litre) was used as a steam generator. This was fitted with a two-hole stopper, one hole carrying a safety tube about 4 to 5 feet high. The other hole was fitted with an outlet tube for the steam, having two exits, one open to the air and the other which could be connected to the reaction vessel. Both these exits could be closed by screw cocks when necessary. The reaction vessel was relatively small compared with the steam generator; it consisted of a 3-litre Wurtz flask. The tube for injection of the steam passed through a one-hole stopper in the neck of the flask, down the neck of the flask, and its lower end was so adjusted as to reach the lowest point in the reaction flask when set up ready for distillation. The side tube of the Wurtz flask was connected to the condenser. The flow of cooling water was adjusted so that during distillation the distillate came over warm (about 60-70°C.). The reaction vessel was fairly tightly packed with the cured material and the whole train of apparatus connected up. All tubing used in this apparatus was of about 0.3 to 0.4 inches in diameter to give a rapid, unobstructed flow of steam. No water was placed in the reaction flask in order to avoid any preliminary heating up period, which is undesirable for the reasons given above. A burner was placed beneath this flask, however, so that it could be lighted at a later stage to prevent any large amount of water from condensing in the reaction vessel. The screw cock between the steam generator and reaction flask was closed and the one opening to the air was opened. The steam generator was heated until a rapid flow of steam was passing out into the air. The outlet was then closed by means of the screw cock and slight pressure allowed to develop in the steam generator, the water rising 2 or 3 feet up the safety tube. The inlet to the reaction vessel next being opened, the steam was injected into it rapidly, and distillation commenced almost at once. The first portions of the distillate were very foul smelling, and the smell was found to be mainly in the aqueous portion. Distinct amounts of oil came over with the first portions of the distillate. It was of a characteristic, pungent odour and was colourless to light yellow.

It was found better not to allow the oil to remain in contact with the aqueous distillate during distillation, but to separate it off in small portions, removing the aqueous layer and placing it in separators for further treatment. This is necessary, since the oil is somewhat soluble

in water; it also appears to emulsify fairly readily with aqueous liquids. The aqueous layers set aside were combined and used for generating steam for later distillations. The water thus became gradually saturated with the oil which was partially recovered in the later distillations. The procedure was also effective in increasing the ultimate yield of oil. In addition, after the last portion of plant material had been distilled, the aqueous liquid was saturated with common salt and extracted with petroleum ether several times in order to extract any emulsified or dissolved oil. The petroleum ether was finally distilled off. As mentioned above, returning the aqueous liquid to the still is not recommended by some authorities, since it is claimed that the prolonged boiling with water partially decomposes the oil and an inferior product is obtained from the later distillations. Others, however, have found that the oil recovered by redistillation of the aqueous distillate is higher in ascaridole than the oil obtained by direct distillation. It is realized that salting out and extraction with petroleum ether is impracticable on a large scale, but in the present instance the investigation was being made experimentally and, since pressure steam, which might have given a better yield, was not available, any procedure which would be informative was regarded as justifiable.

It has been recommended that the material be ground (8) before distillation and this procedure was tried. Two degrees of fineness were used and two methods of grinding. In one method the air-dry material was ground in a Wiley mill using a 1-mm. sieve. This mill runs at a relatively slow speed and does not heat up a great deal, but since most of the seed is less than 1-mm. in diameter very little of it was even cracked. On the other hand, with a finer sieve, the mill tended to stall owing to the fibrous nature of the material, which was especially tough, having been air-dried and not oven-dried. Another sample was ground in a C and N mill. This is a high-speed mill of beater type and grinds very finely; a ½-mm. sieve was used with it. A great deal of heat develops in this mill, however, and although the material was ground finely, owing to its oily nature, it caked together within the mill casing and would not pass through the sieve. The heating of the mill had the further disadvantage that, besides causing loss of oil, it might also cause alteration in its composition.

On attempting to distil this ground material from both mills, but more especially in the case of the finer grinding, it was found that the steam tended to cause pockets and channels through the powder, the whole mass therefore not becoming evenly exposed to the action of the steam, thus reducing considerably the efficiency of the still.

Yield and Results of Analysis.

1. *Sample Received from Sydney.*

Since the amount of material received from Sydney was relatively small, and partial losses occurred in the experimental work, accurate estimations of yield could not be obtained, nor could the oil be satisfactorily investigated chemically. By the methods adopted, however, the total yield of oil was approximately 0.8 to 1.0 per cent. calculated on non-volatile matter at 100°C. On fresh green weight the result would probably be about one-third of this (assuming that the fixed portion of the plant at 100°C. is the same as found for the South Australian grown plant).

The oil was obtained in two fractions as outlined above, and the yield given was calculated for the combined amounts of the two fractions. The fraction obtained by simple steam distillation and separation from the aqueous distillate was almost colourless and moderately unpleasant in odour. It possessed a pungent burning taste resembling a crude Eucalyptus Oil. The fraction obtained by extraction with petroleum ether from the aqueous distillate was deep brown with a more unpleasant odour than the lighter coloured sample; its taste, however, was similar to that of the light coloured fraction. Analysed by the process of the British Pharmacopoeia, the ascaridole content of the lighter coloured fraction was approximately 68 per cent. and that of the darker fraction over 90 per cent. The result for the combination of the two fractions could not be obtained, as the amounts were small and the relative amounts necessary to be mixed to give correct proportions for the oil as a whole could not be determined.

2. *Sample Grown at the Waite Institute.*

As in the case of the sample from Sydney, two fractions were obtained, one by direct distillation and separation and the other by petroleum ether extraction.* The former fraction was distinctly yellower than the corresponding fraction obtained from the Sydney oil, and its odour, though similar, was more unpleasant. The latter fraction was again dark brown, similar to the corresponding fraction of the Sydney sample, and it had a similar unpleasant odour. The taste of both fractions was characteristically pungent and burning like that of the New South Wales sample. Since the two fractions were in correct proportion to each other they were mixed together before determination of the physical characters and analysis. The resulting oil varied from a rich golden colour when viewed in a broad column, to lemon yellow in a narrower tube. The odour and taste were characteristic and similar to previous description.

The yield of oil (calculated on non-volatile matter of the plant at 100°C.) was 1.7 per cent. or about 0.5 per cent. on fresh green weight of the whole plant.

The specific gravity of this oil was 0.9492 (15.5°C.). It was partially but not completely soluble in 10 volumes of 70 per cent. alcohol but gave a distinctly cloudy suspension with from 3 to 8 volumes. The optical rotation was +0.37° (19°C.) and its refractive index 1.4782 (19°C.). The ascaridole content by the process of the British Pharmacopoeia was 65.5 per cent. The oil gives the boiling test of the B.P., continuing to boil for some seconds after removal from the flame when heated to boiling with a fragment of porcelain.

In colour, the oil was somewhat darker than the B.P. requirement, but this is no doubt due to the addition of the portion extracted by petroleum ether which may have been altered by the prolonged boiling water treatment during distillation. The solubility in 70 per cent. alcohol does not perfectly conform to requirements (the oil is required to be soluble in from 3 to 10 volumes of 70 per cent. alcohol). The

* An attempt was made to redistil the aqueous distillate, but only a small amount of a light coloured oil which tended to suspend in water was obtained, so that salting out was resorted to, with subsequent petroleum ether extraction. This oil possibly had a high content of ascaridole, the S.G. of which is very close to 1.0—hence the suspension.

specific gravity is also low (B.P. requires 0.960 to 0.980). The refractive index is within the specified range (1.474 to 1.479) but the optical rotation was +0.37° (19°C.) whereas the B.P. requires —4° to —8° (20°C.). The oil fulfils the requirement for ascaridole, however, this being not less than 65 per cent.

The samples of oil from both the Sydney-grown plants and those at the Waite Institute therefore conform to requirements for the main active principle of *Chenopodium ambrosioides* var. *anthelminticum* as shown by the ascaridole content, and the results for the Sydney-grown plant are relatively high. With reference to the remaining requirements, however, no further work could be done on the Sydney sample owing to lack of material, while in the case of the product from the plants grown at the Waite Institute, only the refractive index conforms to the B.P. requirements.

As mentioned at the beginning of this article, certain samples of the oil which were distilled by Mr. Luff were analysed at the Department of Chemistry at Adelaide. In the table below, results for all samples examined are collected together for comparison. Included in the table are the results for an authentic sample of the oil from W. J. Bush and Company, the well-known manufacturers of essential oils.

Source of Oil.	Sp. Gr.	Optical Rotation.	Refractive Index.	Ascaridole per cent.	Solubility in 3 to 10 vols. 70 per cent. Alcohol.
Sydney plants ..	...	..	..	68 per cent. and 90 per cent. in each fraction respectively	Not tested
Plants grown at Waite Institute	0·9492	+ 0·37°	1·478	65·5	Imperfect, but nearly perfect
Plants grown by Mr. Luff (B)	0·9606	+ 0·25°	1·477	68·8*	Perfect (slowly)
Plants grown by Mr. Luff (C)	0·9156	+ 0·4°	1·479	44·4*	Test negative
W. J. Bush and Co.	0·9772	— 6°	1 478	69·4*	Test perfect (rapidly)
B.P. requirement ..	0·960 to 0·980	— 4° to — 8°	1 474 to 1·479	Not less than 65 per cent.	Soluble

* Results by courtesy of Department of Chemistry, Adelaide.

The B.P. describes the oil as colourless or pale yellow; its odour is characteristic and unpleasant, taste bitter and burning. All samples answered this description.

It will be seen from the table that all samples examined except the sample marked C conform to B.P. requirements as far as the main constituent (ascaridole) is concerned. (The sample marked C was from immature plants.) The refractive index is also within the required range, but in other respects the oils vary considerably from the recognized standards. One outstanding feature is the slight dextrorotation shown by the South Australian oils whereas authorities generally describe the oil as laevorotatory. The authentic sample of W. J. Bush and Company was laevorotatory. The specific gravity of the oil from

the plants grown at the Waite Institute is decidely low, while that from sample C (from immature plants) is lower still; Bush and Company's oil gave a result within the required limits. These variations do not appear to be important, since the ascaridole content is satisfactory; they may only be of importance if they are consequent on the presence of more toxic bodies than ascaridole or those others usually present, in that the safe dose of the oil would then be reduced. This, however, does not appear to be likely. Alternatively, the variation may be due to technique, since none of the samples has been produced under the best conditions. On the other hand, it may well be that the oil from the South Australian grown plants may be found to be always dextro-rotatory and of more variable specific gravity; differences in the effect of altered habitat or even varietal (8) differences may be concerned. Such matters can only be decided by further investigations and accumulated knowledge of the plants and the oil therefrom.

Regarding the yield of oil, some information is available, but it is not always clear whether results are on fresh weight of plant, dry weight, or air-dry material. Such results as could be found are given below, but they do not necessarily indicate yields from South Australian grown plants or even from plants grown in other parts of Australia. Results might also be affected by special methods of cultivation and manuring (1). Konantz (quoted by Weiland (1)) gives 0.96 per cent. in the seed and 0.62 per cent. in the whole plant. In the same bulletin, the seed fruits are quoted as giving 1.08 to 1.12 per cent. "according to variety," and further on 0.29 per cent. to 1.45 per cent. on the green plant is given, depending on the state of maturity. Later again in the article the average oil content of the Chenopodium plant is given as 2.00 per cent. on a dry basis. The British Pharmaceutical Codex gives 1 per cent. of oil from the fruit only. Thorpe's Dictionary of Applied Chemistry and Gildemeister and Hoffmann both give the yield as 0.6 to 1.0 per cent. but do not state on what basis.

In general it may be stated that the yields obtained in the present investigation are very promising and under proper conditions of distillation satisfactory amounts of the oil should be obtainable.

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Pasture Proteins.

A Review of the Knowledge of their Compositions.

*By J. W. H. Lugg, Ph.D., D.Sc., F.I.C.**

Summary.

In the light of current theories, it is possible to assess the nutritive value of a protein from its amino-acid composition. A knowledge of the amino-acid compositions of pasture proteins is thus of considerable importance in the study of stock nutrition.

For reasons which are given in some detail in the text, the subject has received rather reluctant attention and has undergone a correspondingly tardy development. Very considerable progress has been made, however, in the past ten years. The tentative findings are, that the amino-acid compositions of the whole leaf proteins of the angiosperms (to which sub-division the pasture species belong) are almost unaffected by manurial treatment, climate, and age of the leaves; and, further, that the variations in composition between the various angiosperms are quite small.

A table of the amino-acid compositions of the plant leaf-proteins is provided.

The feeding requirements of an animal are satisfied by adequate intake of such materials as carbohydrate, protein, fat, mineral salts, and accessory food substances including vitamins, and the question of the actual amounts of each of these offered in a ration is very important. To some extent replacement of one material by another or by others is permissible, as, for example, fat for carbohydrate and vice versa, or non-protein nitrogenous substances (such as amino acids) for proteins; and, on the other hand, a type of material which may be utilized readily enough by one species of animal may be almost worthless to another, cellulose, for example, being of far more value to ruminants than to carnivores.

It has long been realized that the various proteins may be of very different "nutritive" or "biological" values. With the formulation of the peptide theory of protein structure, studies of the biological values of proteins received new impetus, and before long it became possible to correlate a low biological value with paucity of one or more amino-acid residues in the protein molecule. In fact, the unanticipated deficiencies of certain proteins and amino-acid mixtures as nutrients have more than once indicated the presence of hitherto unrecognized amino-acids in nutritionally adequate proteins.

And so it is generally accepted now that if a protein is digested by an animal, its feeding value (or biological value) is entirely determined by its amino-acid composition. It has been found important, too, to differentiate between the biological values of a single protein employed for different purposes, such as growth, maintenance, and wool production (in the case of sheep), or milk production (in the case of dairy cattle), or egg production (in the case of poultry).

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On the assumption that the amino-acids present in wool keratin could be obtained by the sheep only in a pre-formed condition in the diet, Marston and Robertson (1928) stressed the importance of the cystine intake. Cystine is peculiarly abundant in wool keratin, and they argued that the cystine intake might well be a limiting factor in wool production. Marston (1937), again, has drawn attention to the desirability of providing satisfactory fodder protein for wool growth. The position of cystine in nutrition studies is distinctly uncertain at the moment, recent work by Jackson and Block (1932, 1938), Womack, Kemmerer and Rose (1937), Dawbarn (1938), Beach and White (1939), Tarver and Schmidt (1939) having shown that at least one animal can satisfy its cystine requirements by converting a portion of its methionine intake. For the rat, methionine is an essential amino-acid whilst cystine apparently is not; and the same may hold for the sheep and other animals, both in regard to growth and maintenance and to the production of materials like wool and milk, though it has been claimed by Madden, Noehren, Waraich, and Whipple (1939) that dietary methionine cannot substitute for cystine in the regeneration of plasma proteins in dogs. But cystine may spare methionine in the diet, and in that case, provided that the methionine content is not very low, the cystine plus methionine content will probably serve as a criterion of adequacy or otherwise of the intake of these sulphur-containing amino-acids (*vide* Marston, 1939).

From the fact that casein is rather rich in lysine, Morris and Wright (1933, *a, b*) contended that dietary lysine might well be a limiting factor in milk production. They believed that dietary tryptophan also might be a limiting factor. Arising from feeding trials with spring and autumn fodder leaf crops, Morris, Wright, and Fowler (1936) held that the pasture proteins were of higher nutritive value in the spring than in the autumn.

Clearly, the question of the amino-acid compositions of the proteins and of the non-protein nitrogenous substances of pasture species is the basis of arguments and speculations of this type. A further instance, cited by Chibnall (1939), is that of Crampton and Finlayson's (1935) suggestion that manured grass contains protein of higher biological value than unmanured grass. In fact, it is interesting to note that the three types of speculation referred to cover almost all the circumstances which might be imagined to have some influence upon the composition of a pasture protein—variation with pasture species (Marston and Robertson); variation with season (Morris, Wright, and Fowler); variation with manurial treatment (Crampton and Finlayson).

Fresh plant leaves contain nitrogenous substances other than protein, and this non-protein nitrogen may be as low as 10 per cent. of the whole, or as high as 60 per cent. in the case of etiolated seedlings. For leaf material growing in the light the non-protein nitrogen is generally fairly small in amount. We know very little about its distribution. Some of it occurs in lipoids. The amides asparagine and glutamine are generally present and betaines such as stachydrin have sometimes been found in fair quantity. Of the amino-acids Schulze (1906) reported that he had found, from time to time, valine, leucine, isoleucine, phenyl-alanine, tyrosine, tryptophan, proline, arginine, histidine, and lysine. Shorey (1897) found free glycine in

sugar cane. Vickery (1925) has found arginine, lysine, tyrosine, phenyl-alanine, alanine, valine, leucine, and serine among the non-protein nitrogenous substances of lucerne. These must be accorded nutritive value, but in general the preponderating part of the protein requirements of an animal would be met by the protein in the leaves, not by small amounts of free amides and amino-acids.

Whilst, therefore, the importance of the subject of the composition of pasture proteins has been well recognized (and there were speculations in it long ante-dating those specifically mentioned above) very little practical work has been performed.

Rouelle (1773, *a, b*) appears to have been the first to isolate leaf protein. He obtained it from hemlock juice by heating or by adding alcohol, and purified his protein precipitates by extraction with alcohol. From that time until 1919 leaf proteins were almost neglected, because it had been found very difficult to obtain specimens that were other than grossly impure. In striking contrast stands the volume of work upon the seed proteins, which could often be crystallized and obtained in reasonably pure condition, and were, by virtue of their purity, much more readily amenable to analysis. But by 1920 work was being undertaken by Chibnall and Schryver (1921) in England, and by Osborne and Wakeman (1920) in America, upon the leaf proteins of cabbage and spinach respectively. Osborne, Wakeman, and Leavenworth (1921) obtained large quantities of protein from lucerne leaves and performed a few amino-acid analyses.

Apart from some recent interesting studies in Russia in the more specialized field of plant nucleo-proteins, e.g., Belozersky and Chigirev (1936), Belozersky and Dubrovskaya (1936), most of the work on leaf protein since 1921 has been done by Chibnall and his collaborators. The chief problems have been clearly defined as a rule but not easily solved. They are three in number—(1) the finding of methods of analysis applicable to rather impure protein preparations, (2) the preparation of samples of protein in as high a state of purity as possible, and (3) ensuring that any such sample is what it purports to be, viz., representative of the protein of the entire leaf cells or of certain parts of the cells.

In the past few years the methods of analysis have been improved greatly. Some of them may be applied to grossly impure protein preparations, and thus afford some knowledge of the amino-acid composition of the whole protein contained in the leaves. Thus also they permit a comparison of the composition of the whole leaf protein with that of an extracted sample and provide a rough estimate of the probability that the extracted sample (which is much more amenable to further analyses) is representative of the whole leaf protein. Improvements have been made, too, in the methods of extraction, so that it is now possible with suitable equipment to extract the bulk of the protein from the leaves and obtain it in a relatively higher degree of purity than hitherto.

Except in regard to detail, the methods of extraction are substantially the same as those used by Rouelle nearly 170 years ago. They depend upon macerating the fresh leaf material in such a way that the cell contents are discharged in solution or in a fine state of division whilst

the cell wall material is left coarse enough to be separated by filtering or centrifuging. The protein may then be flocculated by adding acid but it will be relatively impure. If any attempt is made to separate the finely-divided impurities by centrifuging in powerful centrifugal fields or by fine filtration, the chloroplasts may be largely removed and the protein they contain (perhaps 40 per cent. of the entire cell protein) excluded from the sample. Experiments have shown, however, that the bulk of the chloroplast protein may be transferred to the solution by treating the chloroplasts with a very mildly alkaline solution containing alcohol and ether. The leaves must be macerated rather finely if most of the cells are to be ruptured and yield·their contents to the solution, and with the equipment generally available for large-scale work it is difficult to secure fine maceration of the leaves.

In the light of the analytical work performed in the last few years, most of the earlier analyses of the leaf proteins must be discarded. The present findings, which are still rather tentative, are as follows:—

(1) Manurial treatment, climate, and the age of the leaves (factors which markedly influence the proportions of protein, cellulose, and other constituents of the fodder) appear scarcely to affect the composition of the whole leaf protein.

(2) The composition of the whole leaf protein is not the same for all plants, but relatively small variations have been encountered thus far.

(3) The compositions of the whole leaf proteins of the higher (flowering) plants appear to be very similar, sufficiently so, at all events, to warrant their being grouped into a class of proteins. The similarities are particularly marked among members of any one botanical class, e.g., the grasses.

(4) In comparison with the various other proteins which enter into the dietary of man and the lower animals, the leaf proteins appear in a favorable light. The analyses, so far as they go, reveal no deficiencies from the nutritive standpoint in their amino-acid compositions.

The amino-acid compositions of various leaf protein preparations which have been compiled from the following sources:—Chibnall (1939), Lugg (1938, *a, b*, 1939), and Tristram (1939), are shown in Table 1. In some cases it is either certain or reasonably certain that the values quoted are for fully representative leaf proteins. In other cases there is some doubt whether the proteins analysed were fully representative of the protein in the leaves, but there are reasons, which need not be detailed here, for believing that analyses of fully representative proteins would not differ substantially from those given.

The table reveals many gaps. The hydroxy-proline, serine, threonine, and norvaline contents of the leaf proteins have never been estimated. It will be seen that our knowledge of the amounts of glycine, alanine, valine, the leucines, phenylalanine, and proline is confined to single estimations on preparations from a single grass (cocksfoot). Plans are in hand to extend the analyses to preparations from a few other plants whose leaf proteins have already been analysed partially,

and to make extensive analyses of protein preparations from plants which have not previously been examined but are of considerable importance in Australia.

It is to be hoped that further work will not only provide a more complete picture of the compositions of the leaf proteins, but confirm the rather tentative findings already enumerated. These findings have an obviously important bearing upon animal nutrition experiments of the "feeding trial" type, for they reduce to approximate constancy a factor (pasture protein composition) which formerly had to be regarded as a potential variable of extreme complexity.

TABLE 1.—AMINO-ACID CONTENT OF THE LEAF PROTEINS OF PASTURE PLANTS.

(Percentages of the protein nitrogen occurring in the amino-acids and as amide nitrogen.)

—	I. Gramineae.	II. Leguminosae.	III. Chenopodiaceae.
Alanine	4·4‡	..	..
Amide	4·5–5·4	5·2–5·7	5·0–6·0
Arginine	13·4–16·4	14·9–15·4	12·4–14·1
Aspartic acid	4·9–5·4	4·7–5·4	..
Cystine	1·5–1·7	1·2–1·3	1·4–1·5
Di-iodotyrosine	0·0–0·0	0·0	0·0
Glycine	0·4‡	..	..
Glutamic acid	6·6–7·8	6·4–6·6	..
Histidine	1·9–2·6	1·6–2·9	2·1–2·2
Hydroxyglutamic acid*	..	..	..
Hydroxy-proline	..	..	..
Leucine / Isoleucine / Norleucine	8·8†‡	..	..
Lysine	4·9–6·2	6·5–7·0	6·2–6·8
Methionine	1·4–1·7	1·2–1·3	1·4–1·5
Norvaline	..	..	..
Phenylalanine	2·5‡	..	..
Proline	2·0	..	..
Serine	..	..	..
Threonine	..	..	..
Tryptophan	1·6–2·0	1·6–2·0	1·4–2·0
Tyrosine	2·1–2·5	2·4–2·7	2·6–2·7
Valine	4·2‡	..	..

I.—*Dactylis glomerata* (cocksfoot), *Lolium perenne* (perennial rye-grass), *Lolium italicum* (Italian rye-grass), *Cynosurus cristatus* (crested dog's tail), *Festuca rubra* (Chewing's fescue var. Fallax (Hack)), *Festuca duriuscula* (hard fescue), *Poa trivialis* (rough-stalked meadow-grass), *Phleum pratense* (Timothy).

II.—*Medicago sativa* (lucerne), *Trifolium repens* (wild white clover), *Trifolium pratense* (red clover).

III.—*Atriplex nummularium* (old-man saltbush), *Spinacea oleracea* (spinach), *Beta cicla* (beet spinach).

* The evidence for the occurrence of this amino-acid in proteins is very unsatisfactory.

† No attempt was made to separate the three leucine isomers.

‡ These are probably all under-estimated.

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Further Studies of Persistency, Productivity, and Palatability in Selected Introduced Grasses.

*By A. McTaggart, Ph.D.**

Summary.

Sixteen introduced grasses which had shown promise in earlier tests were again studied, from the standpoints of persistency, productivity, and palatability, in swards at Duntroon, A.C.T., in comparison with a native grass and with three old-established standard introductions. The grasses, singly and in pairs, were seeded in quadruplicated plots, with and without subterranean clover.

Data representing percentage ground cover, the general average of which, together with comparison of the averages at the beginning and at the end of the test, provides an indication of persistency, and yields of air-dry herbage are shown in tabulated form. An estimation of relative palatability, based on systematic close observations, of the various grasses is also given.

A histogram, showing graphically the erratic nature of the rainfall during the period of the test, accompanies the tabulated data.

1. Introduction.

In previous publications,† the results obtained from a study of persistency, productivity, and palatability of 55 recently-introduced grasses were published. In this article, the results obtained from similar studies of a selected group of grasses which were promising in the previous studies are given. These grasses are compared with the standard introductions Hawke's Bay (Old Pasture) rye-grass and Akaroa cocksfoot and with the native grass *Danthonia semi-annularis.* They were grown in $\frac{3}{400}$ acre quadruplicated plots, half of each plot being seeded with subterranean clover (2 lb. per acre) and the other half without.

2. Methods.

Following full establishment, at least a year from seeding, data on persistency, productivity, and palatability were obtained as the growth warranted. The average percentage ground cover, as a measure of persistency, was obtained by use of the Point Quadrat method. Quadrat cuttings of a square metre per cut and air-dried weights in grammes of herbage were employed to record productivity. The cuttings were made on 6th October, 1938, 14th November, 1938, 24th March, 1939, 26th September, 1939, 17th November, 1939, and 3rd October, 1940. Scoring individual grasses on the basis of 0 to 10, during and following grazing off, gave an estimate of relative palatability.

3. Results of Studies.

The productivity and the estimated yielding capacity, under the conditions of rainfall, etc., obtaining during the two years are given in Table I.

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* Senior Research Officer (Plant Introduction), Division of Plant Industry.

† Coun. Sci. Ind. Res. (Aust.) Pamphs. 59 and 77, 1935 and 1938.

TABLE I.—PRODUCTIVITY OVER PERIOD OCT. 1938 TO OCT. 1940.*

—	Yields per Square Metre in Grammes of Air-dried Grass. Total Yield from Quadrats (Square Metre). With Subterranean Clover.	Without Subterranean Clover.	Estimated Yield in Tons per Acre for the Two-year Period. With Subterranean Clover.	Without Subterranean Clover.	Estimated Yield Without Subterranean Clover in Comparison with that of Hawkes Bay Rye-grass as Base (100).
Hawkes Bay Rye-grass (old pasture)	546	451	2·2	1·8	100
Bromus arduennensis (2382)	1,008	720	4·0	2·8	159·9
Festuca Mairei (1499) ..	527	352	2·0	1·4	78
Danthonia semiannularis ..	606	407	2·4	1·6	90·4
Agropyron cristatum (1296)	675	426	2·7	1·7	94·4
,, ,, (6607)	575	409	2·3	1·6	90·7
Bromus inermis (1297) ..	634	504	2·5	2·0	111·8
,, ,, (1967) ..	558	398	2·2	1·6	88·3
,, ,, (5545) ..	537	274	2·1	1·1	60·8
F. Mairei and *B. inermis* (1297)	631	418	2·5	1·6	92·6
Brachypodium phoenicoides (1719)	555	210	2·2	0·8	46·5
Phalaris stenoptera (1305) and *B. inermis* (1297) ..	682	490	2·7	1·9	108·6
Dactylis glomerata var. *hispanica* (2145) ..	726	555	2·8	2·2	123·2
Dactylis glomerata v. *hispanica* and Akaroa cocksfoot	702	442	2·8	1·7	98·1
Koeleria eriostachya (2118)	576	171	2·3	0·68	38·0
Bromus polyanthus (2360)..	655	317	2·6	1·2	70·3
Akaroa cocksfoot ..	647	405	2·6	1·6	89·8
Phalaris tuberosa (commercial)	716	452	2·8	1·8	100·4
Agropyron intermedium (1358)	745	498	2·8	2·0	110·5
F. Mairei and *A. intermedium* (1358).. ..	641	504	2·5	2·0	111·9
Phalaris stenoptera (1305)	698	412	2·8	1·6	91·5
Festuca elatior (1144) ..	922	658	3·7	2·6	145·9
F. elatior and *B. inermis* (1297)	577	425	2·3	1·7	94·3
Agropyron caninum (2492)	739	217	2·9	0·8	48·1
,, ,, (2179)	451	264	1·8	1·1	58·6

* In the interests of economy of space, details of the yields obtained on each of the cutting dates have of necessity been omitted. For the same reason, data representing average percentage ground cover have also been omitted.

Examination of the data brought out the following facts:—

Grasses which are outstandingly persistent include:

Phalaris stenoptera (1305).
Phalaris stenoptera (1305) grown with *Bromus inermis* (1297).
Dactylis glomerata var. *hispanica* (2145).
Phalaris tuberosa.

Grasses of fair persistency include: *Bromus inermis* (1967), *Festuca elatior* (1144), *Bromus inermis* (1297), *Agropyron cristatum* (6607), *Festuca elatior* (1144) grown with *Bromus*

inermis (1297), *Agropyron cristatum* (1296), *Bromus arduennensis* (2382), *Festuca Mairei* (1499) grown with *Bromus inermis* (1297), *Agropyron intermedium* (1358).

Grasses which tend to spread with age include the following: *Danthonia semi-annularis* (Selec. B60-37), *Phalaris stenoptera* (1305) grown with *Bromus inermis* (1297), *Dactylis glomerata* var. *hispanica* (2145), *Phalaris tuberosa, D. glomerata* var. *hispanica* grown with Akaroa cocksfoot.

Grasses which do well with subterranean clover are *Festuca Mairei* (1499), *Brachypodium phoenicoides* (1719), *Bromus polyanthus* (2360), *Phalaris tuberosa, Bromus inermis* 1967), and *Phalaris stenoptera* (1305).

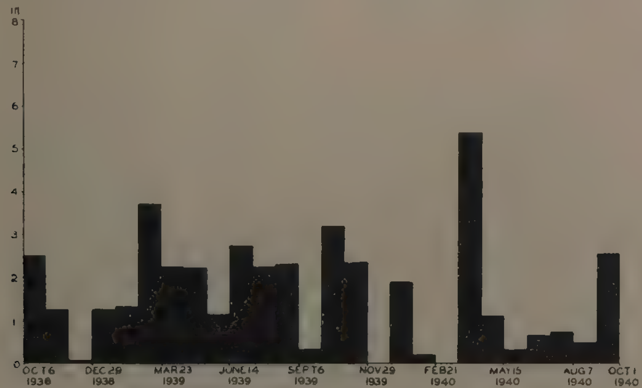
Grasses which are outstandingly productive, despite the dry seasons experienced, are *Bromus arduennensis* (2382), *Festuca elatior* (1144), *Dactylis glomerata* var. *hispanica* (2145). Other good-yielding grasses are: *Festuca Mairei* (1499) grown with *Agropyron intermedium* (1358), *Bromus inermis* (1297), *Agropyron intermedium* (1358), *Phalaris stenoptera* (1305) grown with *Bromus inermis* (1297).

Observations of palatability (to sheep) on these introduced grasses revealed that the species of *Bromus* are the most palatable, followed by strains of *Agropyron cristatum, Agropyron intermedium, Phalaris stenoptera,* and *Dactylis glomerata,* in the order named.

Brief descriptions and the history of the grasses referred to herein will be found in the Council's Pamphlets Nos. 59 and 77.

4. Rainfall Data.

The accompanying histogram shows graphically the rainfall at Duntroon over the period during which the grasses were grown. On the whole, the productivity data reflect the fluctuations in rainfall. The summer rainfalls for 1938-39 and 1939-40, and the winter rainfall for 1940, were abnormally low, as is indicated in the histogram.



RAINFALL AT DUNTROON IN FOUR-WEEKLY PERIODS

5. Acknowledgments.

Acknowledgment is made of assistance rendered by the following colleagues and co-workers: Miss F. E. Allan, M.A., Dip. Ed., Biometrician, who made available the rainfall data and the histogram; W. Hartley, B.A., Assistant Research Officer, who assisted with the field determinations; and J. A. Redpath, who assisted in obtaining the yield data and in applying the sward treatments.

A Note on the Failure of Phenothiazine as an Anthelmintic against *Strongyloides papillosus* of Sheep.

*By G. P. Kauzal, Dr.Med.Vet.**

The only controlled experiment to test the efficiency of phenothiazine against *Strongyloides papillosus* is that of Habermann and Harwood (1940).† They found that: "No strongyloides were eliminated, but 170 of these parasites were found at necropsy in one sheep." Britton (1941)‡ in a review article on phenothiazine states that it is wholly ineffective against Strongyloides.

The worms against which phenothiazine is effective in sheep live in the alimentary tract. Those that inhabit the tissues, such as the liver fluke and trichinella larvae, are not affected in spite of the fact that phenothiazine and certain of its derivatives are partly absorbed into the blood stream. *Strongyloides papillosus* lives embedded in mucus on the intestinal mucosa and may thus be protected from contact with phenothiazine orally administered.

Experimental Procedure.

Twelve lambs, 4 to 5 months old, were selected, and each was infected artificially with 7,500 larvae of *Strongyloides papillosus* on the 5th February, 1941. Faecal egg counts were made at regular intervals from the 13th February to 28th February, and by the latter date the output of parasite eggs was reasonably high. Six of these lambs were drenched on March 3rd with phenothiazine suspension at the rate of 0.6 gramme phenothiazine per kilo body weight. The remaining six lambs served as controls. Faecal egg counts and larval cultures of all lambs were continued for ten days after treatment.

* An officer at the Council's McMaster Animal Health Laboratory, Sydney.

† Habermann, R. T., and Harwood, P. O. (1940).—*Vet. Med.* 35: 24.

‡ Britton, J. W. (1941).—*Cornell Vet.* 31: 1.

Results.

As was expected from previous observations, no larvae appeared in the cultures from the treated group during the two days following treatment. Thereafter, increasing numbers appeared until, by the tenth day, they equalled those developing from the control cultures.

Although the eggs of *S. papillosus* passed in the faeces for two days after treatment completely failed to develop, there was no reduction in the number of eggs passed during this period. In one sheep there was a slight drop in the faecal egg count the day after treatment, but it had risen again to the previous level 24 hours later. It is apparent, therefore, that the adult worms remained unaffected by the chemical and laid their normal quota of eggs, and that the phenothiazine prevented the development of the eggs so long as it was present in the faeces in relatively high concentration. The average number of eggs per gramme of faeces in the treated group before treatment ranged from 900 to 13,200, whereas, after treatment, it ranged from 1,000 to 20,100. Comparable figures for the control group were 1,200 to 3,000 and 1,300 to 3,500.

Conclusions.

Phenothiazine in a dose of 0.6 g. per kilo body weight administered to lambs 4 to 5 months old has no effect on *Strongyloides papillosus*, and the egg production of the females is unaffected. It prevents further development of the eggs passed during the two days following treatment, but thereafter the normal rate of development of larvae gradually recurs.

A Convenient Accessory for the Rapid Microscopic Examination of Dry-Mount Objects.

By J. A. Tubb, M.Sc. and Andrew Proctor.**

In the course of studies on the age and rate of growth of the Australian "salmon" (*Arripis trutta*), the scales of these fish were found to present a number of problems, one of the most important of which was that of preparing the scales for "reading".

The scales of the Australian "salmon" are massive and convex and, when dry, become extremely elastic. Considerable pressure was necessary to flatten the scales before insertion in the projector or under the compound microscope. Owing to the size of the scales, most of which were from ¼ in. to ⅝ in. in diameter, each had to be handled separately, and the amount of time occupied in preparing them was inordinately great.

To facilitate the work a "Clamp Slide" was designed and constructed by the authors, and it has proved an extremely efficient and time-saving device.

The accompanying photographs show the construction and use of the "Clamp Slide", which is readily adaptable to the many classes of microscope work wherein temporary mounts only are required. Plate 1, Figs. 1 and 2, show the "Clamp Slide" with specimen in position and the spring-hinged clamp open. Plate 2, Figs. 1 and 2, show how much clearer is the dry mounted specimen than the one mounted in glycerine jelly.

Details of Construction.

The base consists of heavy sheet brass 4 in. x 1½ in. x 5/64 in., in the centre of which a flanged rectangular hole is cut to receive the lower glass plate. This plate, cut from an ordinary plain glass microscope slide, measures 1½ in. x 1 in. on the surface, and is cemented on to the brass base plate.

The upper plate or clamp consists of a sheet of the same gauge brass cut to form a frame for the upper glass plate, which has the same dimensions as the lower. The dimensions of the clamp are 3½ in. x 1½ in. x 5/64 in.

One end of the clamp is screwed to the "free" half of a 1½-in. brass hinge which is provided with a stout spiral spring on the hinge spindle. A strip of 20-gauge brass, 1½ in. x ⅜ in., is screwed on top and bent to project over and beyond the hinge spindle to form a lever for raising the clamp. The "fixed" half of the hinge is then screwed on to the base plate so that the glass slips are in contact.

By scribing the upper or lower glass plate, this device may be used for the direct measuring of micro-objects.

* An officer of the Division of Fisheries.

PLATE 1.

FIG. 1.—Clamp Slide, showing fish scale in position.

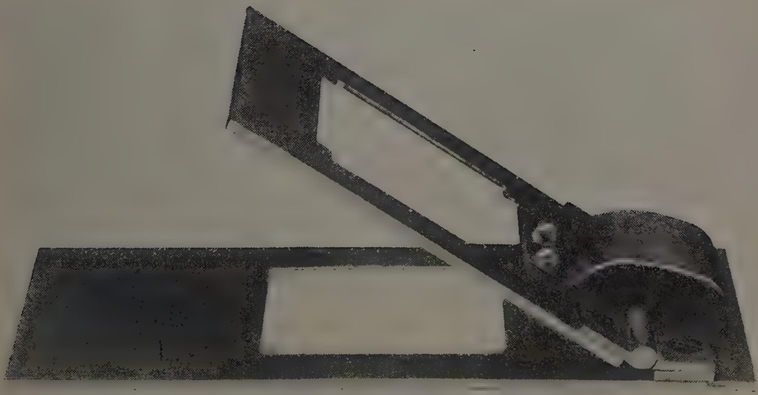
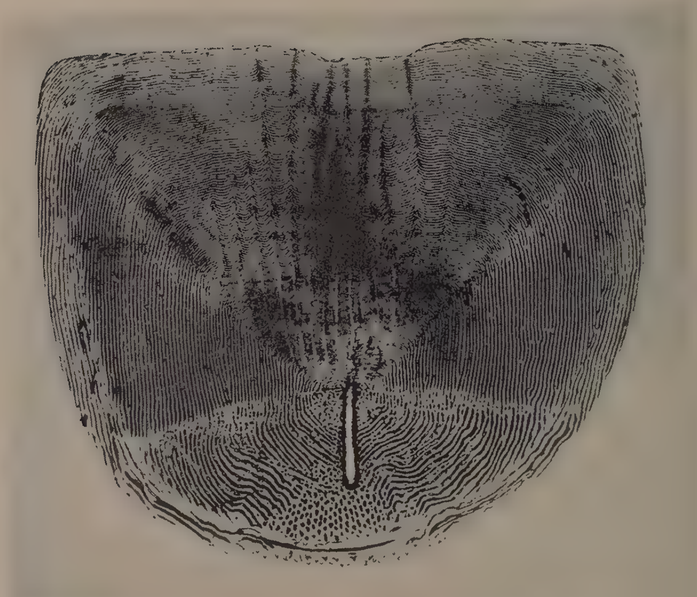


FIG. 2.—Clamp Slide, showing spring-hinged clamp, open.

PLATE 2.



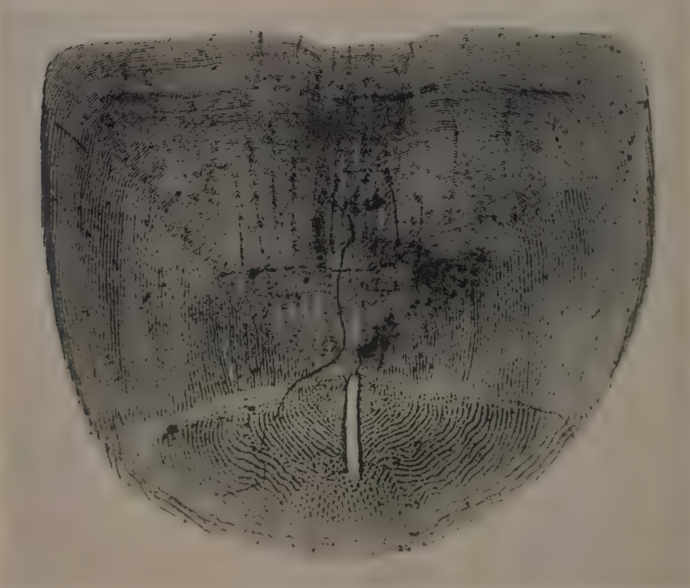


Fig. 1 (above).—Photograph of mullet scale mounted in Clamp Slide.

Fig. 2 (below).—Photograph of same mullet scale mounted in glycerine jelly.

NOTES.

Agar-agar, A New Potential Industry in Australia.

(*Contributed by the Division of Fisheries.*)

In October of last year a sample of a red seaweed, *Gracilaria confervoides,* was sent to the Fisheries Division of the Council for Scientific and Industrial Research, by Mr. Laver of the State Fisheries Department. The seaweed had been discovered in quantity at Bateman's Bay by Colonel Pilmer, who had recognized its qualities. Experiments were thereupon begun by an officer of the Fisheries Division, and a high quality sample of commercial agar-agar was prepared. Subsequent samples have been analysed and show properties on the whole equal to agar previously imported from Japan.

Agar-agar was used in Australia before the war for many purposes, including certain canned meats, confectionery, and other products. It also has uses in the paint and leather industries, but most important from a defence point of view are its uses in the preparation of bacteriological media and in surgical dressings. The consumption of agar for this purpose is of the order of half a ton per annum, and the total consumption in 1938 was 71 tons, at a price ranging from 3s. to 5s. per lb., all imported from Japan.

The Fisheries Division has worked out the details of a process for which a pilot plant is to be erected to clear up a few problems related to the translation of the process from the laboratory scale to the commercial. This plant with some modification will be able in emergency to supply Australia's medical needs, if required.

In studying the occurrences of *Gracilaria,* Mr. R. Bouchier of Cronulla has rendered valuable services to the Division, and beds of this weed are known to exist in at least four estuaries on the south-east coast of Australia, as well as in the Swan River in Western Australia. Mr. Bouchier's suggestion led to the discovery of a large tonnage of the seaweed washed up on a beach close to Sydney, and it is expected that further deposits of the weed will be washed up in known places during the next few months. Reports from other sources indicate that *Gracilaria* is widespread and that supplies of raw material will be abundant for large scale manufacture.

The seaweed is shaken free from sand, preferably by washing at the water's edge, and is hung on hurdles to dry and bleach with the sun, rain, and air. When thoroughly dry, it is baled up and sent to the factory. Not more than 5 per cent. sand and 20 per cent. total moisture are allowed for the seaweed to bring top price. The cost of harvesting has yet to be assessed, and will vary with the purity of the deposits of weed.

Baled weed will keep almost indefinitely, but moisture causes mould growth and rotting. The dried *Gracilaria* somewhat resembles hemp in appearance and texture. Its manufacture is relatively simple. It is washed for two to four days in running water to remove the salt, and then placed in wire baskets and boiled with water at 230° to 240°F.

In this way it is given three successive boilings, the liquor from the last boiling being used for the second, that from the second for the first and so on. The liquor from the first vat is then filtered, or, if a high quality product is required, cleared with charcoal, and then filtered using a filter-aid such as filter-cel or an Australian equivalent. It can be filtered at 212°F. or higher and only sets at about 110°F. After filtration it is allowed to set, care having been taken to keep the concentration of the liquor as high as possible during extraction to produce a firm gel. The gel is then cut into fine strips about ¼-inch in section, laid on trays and frozen overnight. It can then be dried in the sun or in a drying tunnel, and strips similar in appearance to the Japanese strip-agar are produced.

The greater the care used in filtration the less the need for the freezing and thawing of the gel which is a method of purification. Commercial houses are used to the transparent strips of agar and their reaction to other forms such as powdered agar produced by direct drying from the filter-press liquor remains to be seen.

No complete survey of all possible areas of occurrence of *Gracilaria* has been made or is even contemplated by the Fisheries Division at the present time, owing to pressure of other work, but sufficient locations are known for the Division to feel confident that it is time to recommend the commercial undertaking of an agar industry in Australia, so as to make use of this year's harvest of seaweed. It is believed that such an industry will be able to compete on the overseas market after the war owing to the comparative ease with which this particular species of *Gracilaria* can apparently be harvested.

A great deal of work remains to be done to study the rate and density of growth of the seaweed and to ensure a continuity of supply for the future. A large export trade may be possible, while present knowledge seems to allow of a steady supply to meet all or most of Australia's essential needs.

The Commercial Development of the C.S.I.R. Process for the Preservation of Veneer against the Attacks of the Powder Post Borer (*Lyctus brunneus* Stephens).

The problem of the protection of timber against the attacks of the powder post borer is of world-wide interest. Overseas, however, methods that have been developed are aimed, mainly, at affording temporary protection only. If the treated timber is cut, or the protective skin broken in any way, it is practically certain that the untreated area that is exposed will be attacked. Any treatment to be effective must render the timber immune to infestation. All experimental work carried out at the Division of Forest Products has been planned with this end in view.

When the investigation was first commenced, it was found necessary to develop a satisfactory testing technique so that the effectiveness of different chemicals and of different concentrations of the same chemical could be compared. A simple, reliable procedure was developed and a large series of different chemicals tested over a period of several years. These tests showed that sodium fluosilicate and boric acid were effective

in relatively small amounts. Sodium fluosilicate was the more toxic chemical to the young lyctus larvae, and some commercial tests were made with this material at Austral Plywoods, Brisbane. About this time, however, the results of an extensive study of fluorine intoxication were published, which indicated that the use of sodium fluosilicate for the treatment of veneers would result in a serious health hazard. This hazard would be particularly high in the case of sanding machine and trim-saw operations.

Further work was commenced in the laboratory using boric acid, borax, mixtures of boric acid and borax, and zinc chloride. Boric acid was finally chosen as the most suitable chemical, and treating schedules were developed for a number of species and thicknesses of veneer. Green veneer was used for this work, since it was considered uneconomical to treat dry veneer and thus have to re-dry before gluing-up.

At this stage it was considered desirable to carry out large scale tests in the field. The management of Brisbane Sawmills Ltd., Windsor, Queensland, who were particularly interested in the process, offered to build a treating vat, supply the veneer, and undertake a series of tests under the control of an officer of the Division of Forest Products. This offer was accepted. Upon the completion of the work it had been clearly proved that the schedules developed in the laboratory could be applied in the field and that the process as a whole was definitely a commercial proposition.

For years the wide bands of susceptible sapwood of many of our choicest veneering timbers had been wasted, as experience had shown that the use of this material would be sure to lead to claims for replacement on the appearance of borer attack. Some manufacturers were thus a little sceptical of the hundred per cent. efficiency of the process and were hesitant in installing the requisite treating plant. This reluctance to make such a radical change in manufacturing technique was soon overcome and at the present time eight plywood mills in Queensland and four in New South Wales are utilizing the new process. One plant operates two treating tanks and is considering the installation of a third. The process has been in commercial use for approximately two years, and during that period not one complaint has been received regarding borer attack in treated timber.

Estimates have not been made, as yet, of the volume of veneer treated by the new process, but there is no doubt that an enormous saving of money and timber has been effected.

The successful results obtained from the treatment of veneer soon led to numerous inquiries for methods of borer-proofing solid timber up to 2 inches thick. To impregnate timber of this thickness adequately is a different proposition from treating 1/40-in., 1/16-in., $\frac{1}{8}$-in., or 3/16-in. veneer. The problem was tackled in the laboratory, however, and it was found that by increasing the concentration of the treating solutions and the treatment period, 2-in. boards could be rendered immune to attack. Further experiments on a semi-commercial scale are now under way in order to obtain data on the design of suitable treating vats and on the economics of the process. When these are completed it is anticipated that at least six firms will immediately install the necessary plant to treat material which to a large extent is wasted at the present time.

Report of Thailand Department of Science, 1936-38.

The ninth biennial report of the Thailand Department of Science describes a great increase in the activities of the Department. One form of expansion is the addition of a Division of Pharmacy to the Divisions of Chemistry, Agricultural Science, and Industrial Chemistry, already in existence. The new Division will undertake research into indigenous drugs and the manufacture of certain galenical preparations, and it will examine and standardize drugs and biological preparations imported into, or manufactured in, Thailand. The Division is housed in a modern two-storied building containing offices, balance rooms, and six laboratories.

The Division of Industrial Chemistry, formerly known as the Division of Technology, was exclusively devoted to the manufacture of Vitamin B_1 extract and drugs for the treatment of leprosy; the Vitamin B_1 extract is obtained from rice bran, and 1,600 litres of it were prepared during the two years under review. A Ceramics Section has now been incorporated in this Division, and the workshop attached to the Division has been considerably enlarged so that it is able to construct much of the apparatus previously imported or manufactured outside the Department. The Division of Agricultural Science is largely engaged on soil surveys and analyses, but it also analysed various foods and animal fodders, and investigated the fertilizing values of bat and swallow guano. The Division of Chemistry carries out large numbers of routine assays of opium dross submitted by the Excise and Opium Department, and of bronze for coinage, submitted by the Treasury Department. It also has a Water Analysis Section which is growing in magnitude each year as water works are being started in most of the important towns of the kingdom.

The production of solar salt, and the production and utilization of soya beans, are two important problems that have been investigated by committees set up by the Department of Science. Analyses of Thai soya beans show that their nutritional value is comparable to the Manchurian species.

During 1936-38, six officers of the Department were sent abroad to gain experience, principally in the fields of pharmaceutical chemistry, spectrography, ceramics, and petroleum refining.

Reviews.

"The Chemistry and Technology of Marine Animal Oils with Particular Reference to those of Canada," edited by H. N. Brocklesby.

(Bulletin LIX. of the Fisheries Research Board of Canada, Ottawa, 1941, pp. 431, figs. 73. Available on application to the Editor, Fisheries Research Board of Canada, Toronto 5, Canada. Price $2.95 (paper-bound), $3.80 (cloth-bound).)

This is revision of Bulletin XXXVII. and contains much new material. The chemistry and composition and properties of marine animal oils and fats are fully dealt with, including those important

constituents the vitamins. Rancidity is discussed, and a critical survey made of the latest researches on the subject. The section on the production of fish oils is adequately treated as is also the section on refining and processing. All these matters are of great interest to Australia at present, where a new fish oil industry has been established for the production of medicinal liver oils. Unfortunately from the point of view of the oil research chemist, there is little information and no critical study of the methods of testing for Vitamins A and D. The use of the spectrophotometer for Vitamin A has emphasized the need for a statement of the evidence for fixing a conversion factor—the Americans use 2,000, while British scientists usually prefer 1,600. As regards Vitamin D, much work has been done on the use of the spectrophotometer, and of an antimony trichloride method for determining Vitamin D, and a critical survey of this work would have been of great value.

We, in Australia, are not concerned at the moment with the problem of the utilization of fish oils, as there does not appear to be any immediate prospect of local supplies of such oils for other purposes than medicinal use or for the feeding of stock, but this section is as complete and informative as the rest of the Bulletin.

The revised edition of the Bulletin is an excellent volume for use as a handbook by any one interested in fish oil production, and with its bibliography is a most useful reference book for the oil-chemist. It is rather large for the paper cover in which it is bound, and deserves to be sent straight to the bookbinder for a more permanent cover.

"Haricot Beans," by G. St. C. Feildon.

(Occasional Paper 6 of the Imperial Bureau of Horticulture and Plantation Crops, East Malling, Kent, England, 1941, pp. 20, bibl. 22. Price 1s.)

This Bulletin was compiled at the request of the Ministry of Agriculture, London, primarily to help those intending to grow haricot beans for private or commercial purposes in the U.K.

In the past, cheap supplies of beans from North America, Japan, and Hungary have discouraged the farmer from putting his money into a crop which in England is only likely to achieve full success in years of dry summer. But in wartime with overseas supplies greatly reduced, it has seemed reasonable to examine the possibility of providing a valuable addition to the national menu by growing those varieties that, by their yields of 1 ton or more per acre in 1940, have shown a certain adaptability to English conditions.

The Bulletin contains a brief account of work with haricots in U.S. and Canada and of the results of experiments in England at Wisley, Cambridge, and elsewhere. Cultivation methods are outlined and varietal characteristics discussed.

The information should, it is thought, prove of interest to possible growers in North America, New Zealand, and other lands of temperate climate.

"VICTORIAN FUNGI," by James H. Willis, B.Sc., of the National Herbarium of Victoria.

(Pp. 72, plates 16 (3 coloured), figs. 18. Published by the Field Naturalists Club of Victoria, 1941. Distributed by Robertson & Mullens Ltd., Melbourne. Price 2s. 6d.)

Professionals and amateurs who are interested in the identification of fungi should find this booklet a useful guide. The fungi described are by no means confined to the State of Victoria, consequently the booklet may be used for identification in other parts of Australia.

Any who have attempted identification of fungi with the aid of the references hitherto available know the difficulties that beset systematic mycologists in Australia. This publication by the F.N.C.V. will help to overcome some of these difficulties.

A key to genera and 120 species of Agaricaceae and some other fungi is provided, and it appears to be a convenient one. This is followed by descriptive notes that are well illustrated by excellent photographs, accurate drawings, and three coloured plates.

The reviewer hopes that booklets on other groups of Victorian fungi will follow along the lines of this one.

The Carob Bean—A Correction.

From a brochure recently issued by Karoub Estates (Aust.), an impression might be gained that the Council for Scientific and Industrial Research, in a summary of information on the Carob Tree (*Ceratonia siliqua*) prepared in 1940, had suggested a number of uses and markets for the bean: in particular, the Council might be assumed to have stated that the beans when roasted make an excellent substitute for coffee and that the ground seed makes excellent bakelite.

Actually, this summary was just an outline of the literature on the subject, and all papers consulted were cited. Tagliani, in 1929, suggested that roasted pods could be used as a coffee substitute; nothing more was added to this reference. Bakelite was not mentioned in the summary.

Recent Publications of the Council.

Since the last issue of the *Journal*, the following publications of the Council have been issued:—

Bulletin No. 138.—"The Economic Biology of Some Australian Clupeoid Fish," by M. Blackburn, M.Sc.

This Bulletin describes seven kinds of Australian fish, namely, the pilchard, southern herring, sprat, sandy sprat, blue sprat, maray, and anchovy. All these fish belong to the clupeoid group—a group which is second to none in importance in other parts of the world. However, in Australia, despite the fact that the group has long been known to be well represented in our water, no serious attempt has ever been made to base a commercial fishery on it. It was, therefore, felt necessary to make a consideration of this group one of the primary objectives of the Council's Fisheries Division. The Bulletin comprises the results of the investigations to date, but it is naturally an interim report and much further work, particularly on the distribution and method of catching, is necessary.

Although none of the fish described are commercially utilized in Australia at present, they would all be suitable for canning if they could be obtained in sufficient quantity. Their oil content is not high, but they would be suitable for the production of fish meal.

Bulletin No. 139.—"The Soils of Tasmania," by C. G. Stephens, M.Sc., A.A.C.I.

The information on the soils, climate, and vegetation of Tasmania, contained in this Bulletin, has been collected over a period of ten years. Taken as a whole, Tasmania is a locality of podsolic soils, normal podsols being the most widespread type. High-moor peats are characteristic of the elevated plateaux and mountain ranges in the rugged parts of the State, and button-grass plain soils occupy the western and south-western coastal regions. Basaltic soils occur chiefly on the north-west coast.

The major soil problems of the State are the restoration of the fertility of the basaltic and ancient eroded ironstone gravel soils of the Cressy and Longford districts, and the problem of erosion control. Loss of fertility in the districts mentioned is probably due to the reversion of applied phosphate, and applications of lime and coarse-grained superphosphate, &c., are being investigated as means of checking this reversion. Sheet erosion is common on the slopes of the apple-growing soils of southern Tasmania and on the basaltic soils; it may not be obvious on casual inspection, but a critical examination of the depth of organic matter of the surface soil leaves no doubt that erosion is more widespread than is usually credited. Gully and sheet erosion also occur on the black soil south-east of Launceston. The stabilization of the sand dunes on the north-east coast is another serious problem; the dunes should definitely be excluded from grazing.

The Bulletin contains a soil map of Tasmania and other maps and diagrams which demonstrate the relationship of soil type and climate to agricultural and pastoral production in the various districts.

Pamphlet No. 106.—"Agricultural Features of the Australian Potato Industry," by J. G. Bald, M.Agr.Sc., Ph.D.

This Pamphlet summarizes the results of a survey of the potato industry of Australia. Although the survey also covered the economics of production and marketing, it is the more purely agricultural features of the industry which are dealt with in the Pamphlet. The chief potato-growing soils and their manurial requirements, the agricultural methods used, the varieties of potato grown, and their diseases and pests are included in the discussion.

Most potato growers do not make sufficient provision for maintaining the fertility of the soil; pastures should always be included in the crop rotation, and suitable manures should be applied. It is estimated that in Australia the total yield of potatoes is reduced by diseases and pests to about four-fifths of what it should be. The "running out" of potato stocks is mainly due to infection with virus diseases, which may best be controlled by the planting of virus-free seed tubers. In this connexion, the value of the various Certification Schemes for producing good seed stocks cannot be over emphasized. The most destructive insect pest of potatoes in all regions of Australia is the potato moth; control measures for this insect rely on preventing infestation, as sprays and dusts are not effective.

There is scope for a good deal of improvement in the varieties of potatoes grown in Australia, and the industry would be greatly benefited if varieties could be bred which were resistant to the more important diseases and to such climatic conditions as drought and frost.

Pamphlet No. 107.—" Food Composition Tables," compiled by H. R. Marston and Mary C. Dawbarn.

The Council was recently asked to prepare these tables in connexion with the planning of army rations on a scientific basis. Such rapid advances are being made in the knowledge of food composition, particularly as regards vitamins, that the older published information is often contradictory and may be seriously misleading. Present methods of estimating vitamins show that many earlier methods gave unreliable results; accordingly, it was necessary for the Council's officers to examine critically a vast amount of scientific literature in order to sift out the most reliable values. This work, which could only be undertaken by investigators with long experience of the subject, was carried out by members of the staff of the Council's Nutrition Laboratory in Adelaide.

Forthcoming Publications of the Council.

At the present time the following future publications of the Council are in the press :—

Bulletin No. 140.—" Foot-Rot in Sheep. A Transmissible Disease Due to Infection with *Fusiformis nodosus* (n.sp.). Studies of its Cause, Epidemiology, and Control," by W. I. B. Beveridge, D.V.Sc.

Bulletin No. 141.—" A Soil Survey of the Waikerie Irrigation Area, South Australia," by R. I. Herriot, B.Ag.Sc., and E. J. Johnston, B.Sc.Agr.

Bulletin No. 142.—" A Soil and Land Use Survey of the Hundreds of Riddoch, Hindmarsh, Grey, Young, and Nangwarry, County Grey, South Australia," by C. G. Stephens, M.Sc., A.A.C.I., R. L. Crocker, M.Sc., B. Butler, B.Ag.Sc., and R. Smith, B.Ag.Sc.

Pamphlet No. 108.—" Studies on some Ectoparasites of Sheep and their Control. 1. Observations on the Bionomics of the Sheep Ked (*Melophagus ovinus*)," by N. P. H. Graham, B.V.Sc., and K. L. Taylor, B.Agr.Sc. 2. " Chemical and Biological Studies on Certain Arsenical Dipping Fluids," by M. R. Freney, B.Sc., M. Lipson, B.Sc., and N. P. H. Graham, B.V.Sc. 3. " Chemical Observations on Commercial Powder Sheep Dips with Special Reference to their Arsenic Content," by M. Lipson, B.Sc.

Pamphlet No. 109.—" Studies on the Physiology and Toxicology of Blowflies. 8. Rate of Ammonia Production by Larvae of *Lucilia cuprina* and its distribution in this Insect. 9. The Enzymes Responsible for Ammonia Production by Larvae of *Lucilia cuprina*," by F. G. Lennox, M.Sc., A.I.C.

H. E. DAW, Government Printer, Melbourne.

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